Spring 4-12-2016

Fulfilling the promise of the Paris Agreement: The role of efficiency and renewable energy

Chuck Kutscher
NREL, chuck.kutscher@nrel.gov

Fulfilling the Promise of the Paris Agreement: The Role of Efficiency and Renewable Energy

CO2 Summit II:
Technologies and Opportunities
Santa Ana Pueblo, NM
April 12, 2016

Chuck Kutscher
National Renewable Energy Laboratory

the ONION
America's Finest News Source

NEWS

Report: Global Warming Issue From 2 Or 3 Years Ago May Still Be Problem

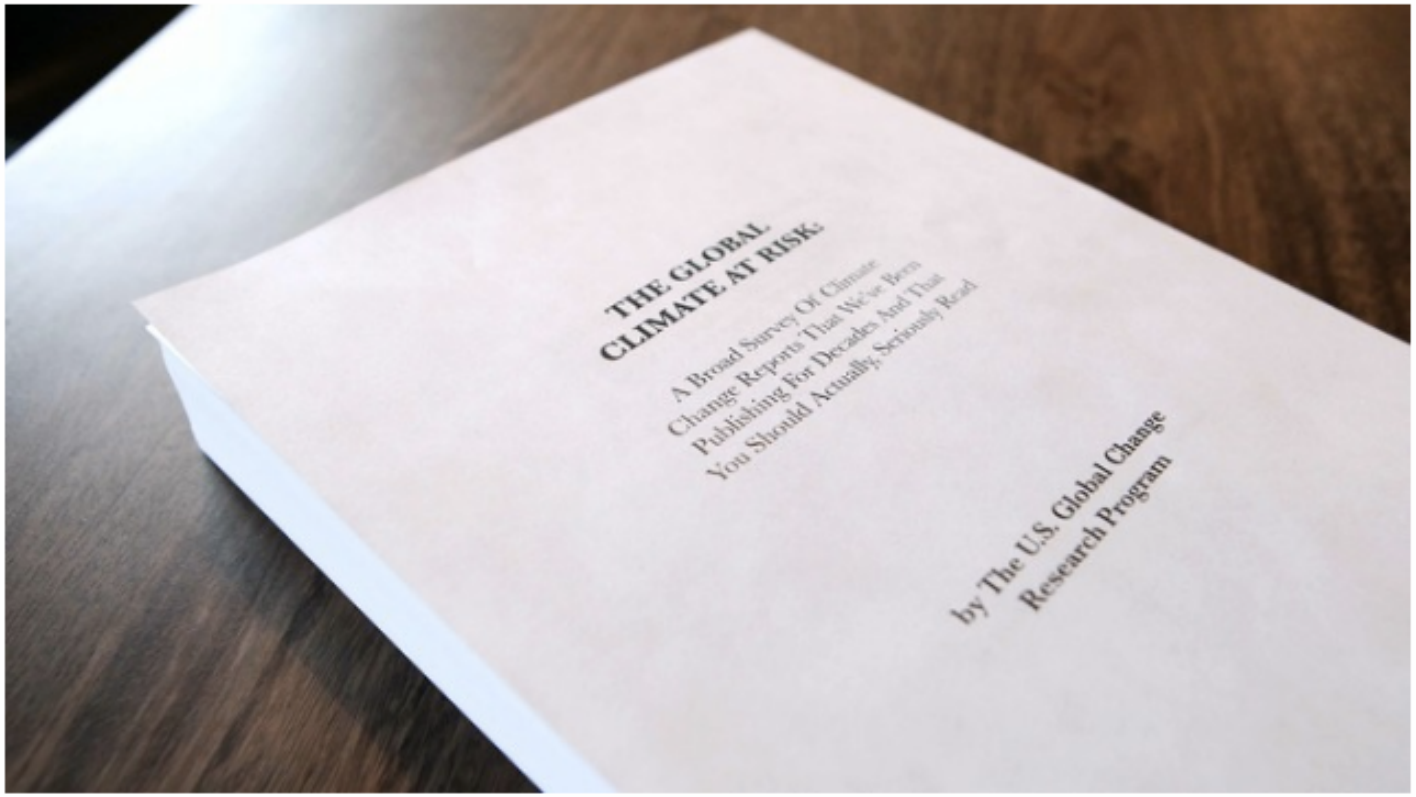
NOVEMBER 10, 2010 | ISSUE 46•45

WASHINGTON—According to a report released this week by the Center for Global Development, climate change, the popular mid-2000s issue that raised awareness of the fact that the earth's continuous rise in temperature will have catastrophic ecological effects, has apparently not been resolved, and may still be a problem.

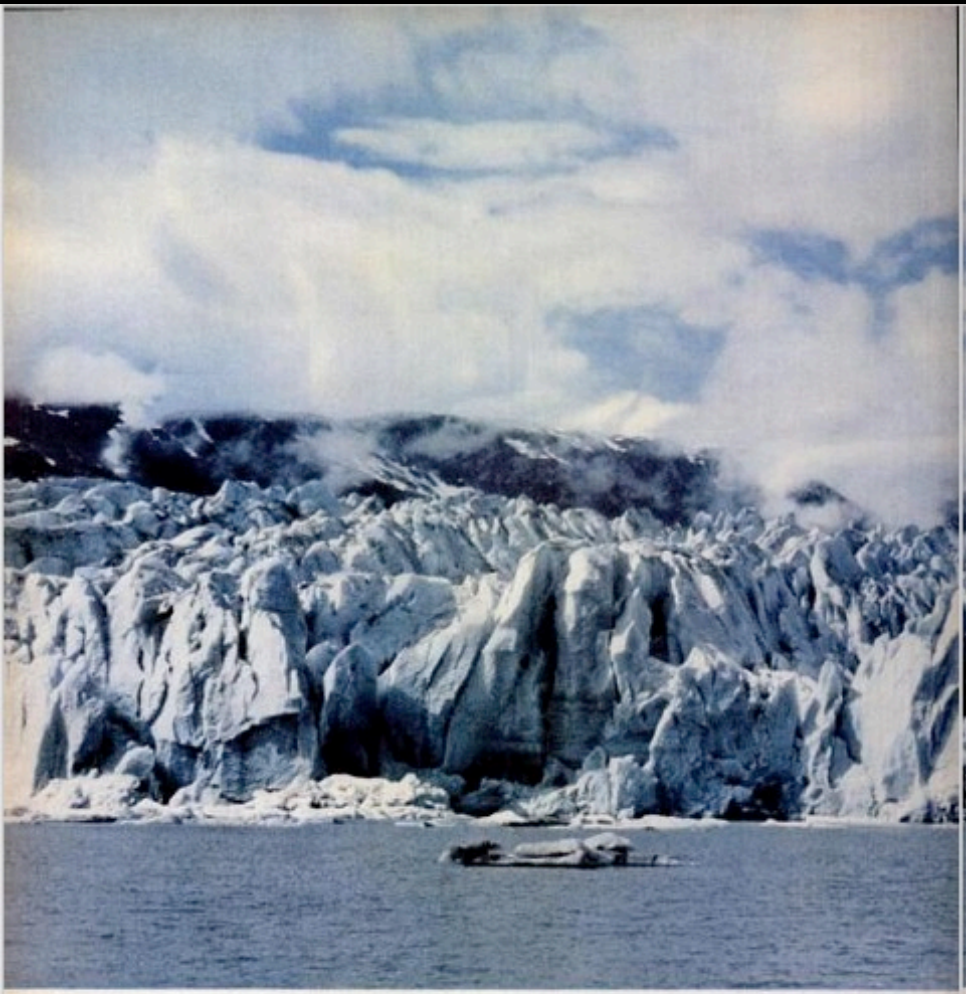
the ONION
America's Finest News Source

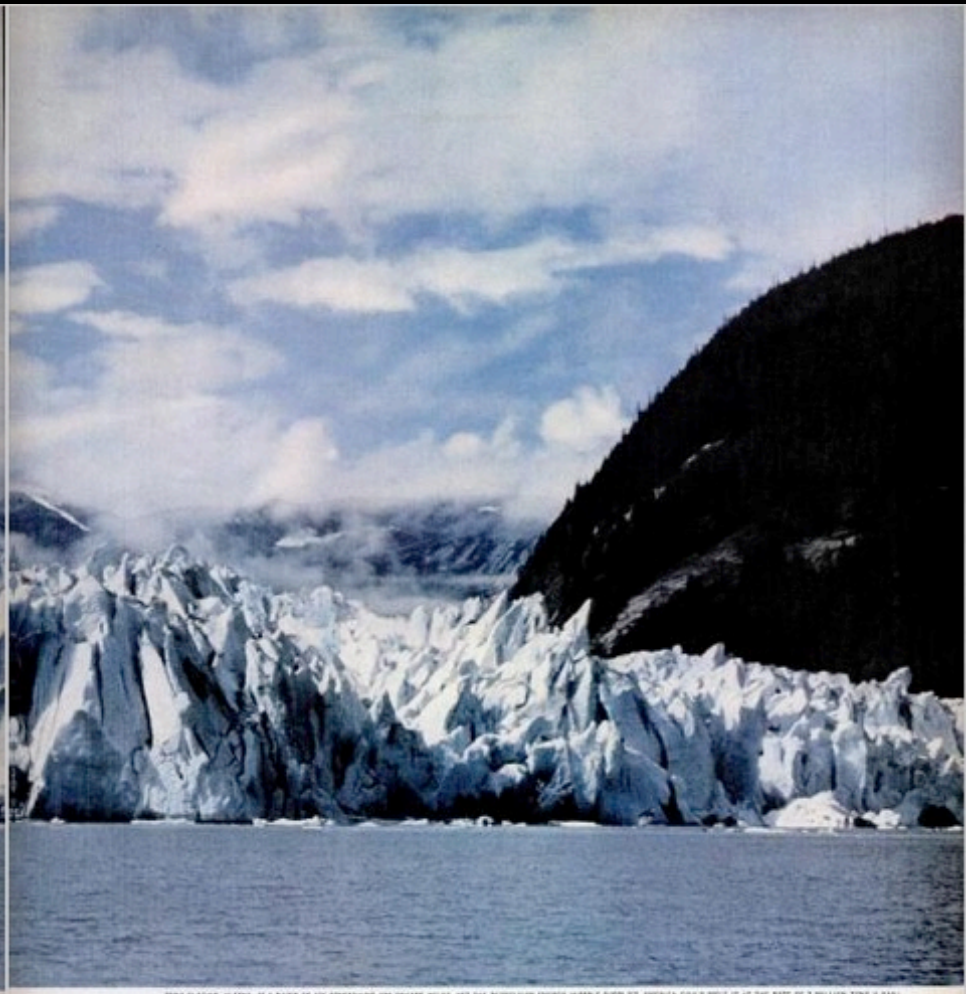
New Climate Change Study Just 400 Pages Of Scientists Telling Americans To Read Previous Climate Change Studies

NEWS IN BRIEF · Science & Technology · Science · ISSUE 51·02 · Jan 14, 2015



1962 Magazine Ad





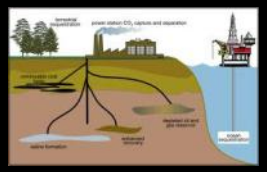
EACH DAY HUMBLE SUPPLIES ENOUGH *ENERGY* TO MELT 7 MILLION TONS OF GLACIER!

This giant glacier has remained unmelted for centuries. Yet, the petroleum energy Humble supplies—if converted into heat—could melt it at the rate of 80 tons each second! To meet the nation's growing needs for energy, Humble has applied science to nature's resources to become America's Leading Energy Company. Working wonders with oil through research, Humble provides energy in many forms—to help heat our homes, power our transportation, and to furnish industry with a great variety of versatile chemicals. Stop at a Humble station for new Enco Extra gasoline, and see why the "Happy Motoring" Sign is the World's First Choice!

HUMBLE
OIL & REFINING COMPANY
America's Leading Energy company

The Goal:
Reduce all carbon emissions to zero as rapidly as possible!

Carbon-Free Energy Options



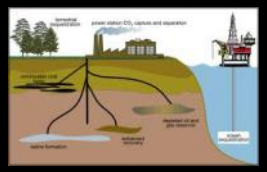
Carbon capture & storage

Nuclear

Efficiency

Renewable Energy

Carbon-Free Energy Options



Carbon capture & storage

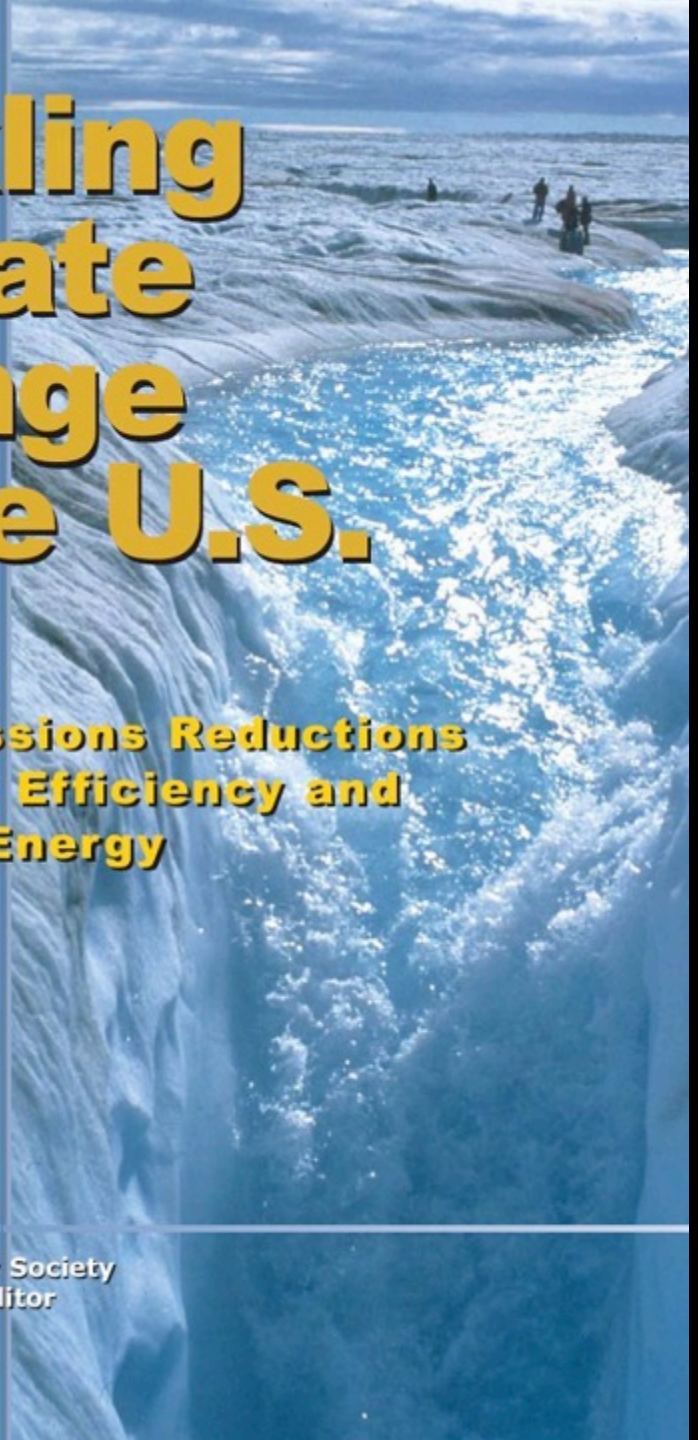
Nuclear

Efficiency

Renewable Energy

Tackling Climate Change in the U.S.

Potential Carbon Emissions Reductions from Energy Efficiency and Renewable Energy by 2030



American Solar Energy Society
Charles F. Kutscher, Editor
January 2007

Geothermal

PV

Biofuels

Efficiency

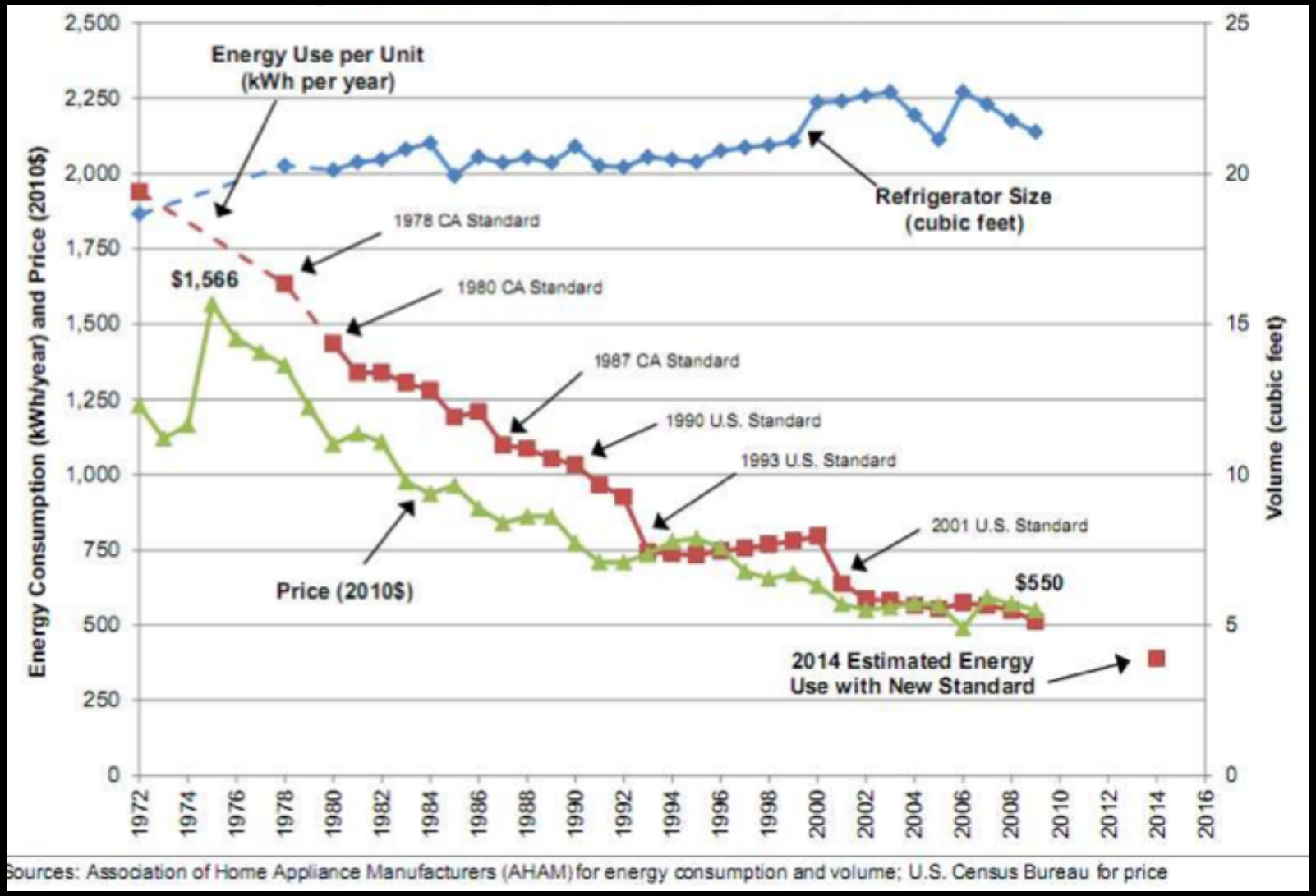
CSP

Biomass

Wind

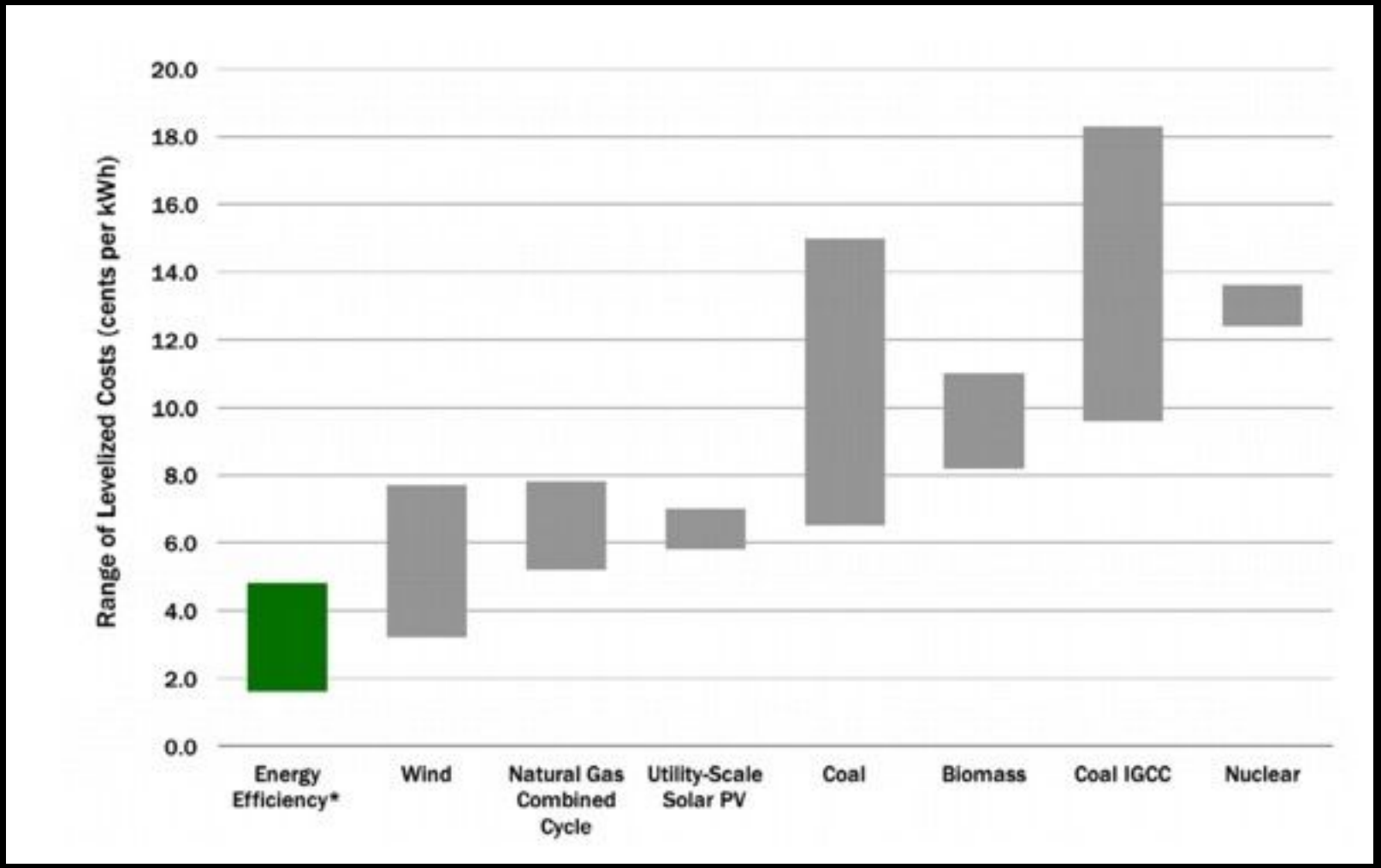
Building Energy Efficiency

Average US Home Refrigerator Energy Use, Volume and Price vs. Time



Sources: Association of Home Appliance Manufacturers (AHAM) for energy consumption and volume; U.S. Census Bureau for price

Negawatts Are Cheaper than Megawatts



Energy Performance-Based Contracting: NREL Research Support Facility

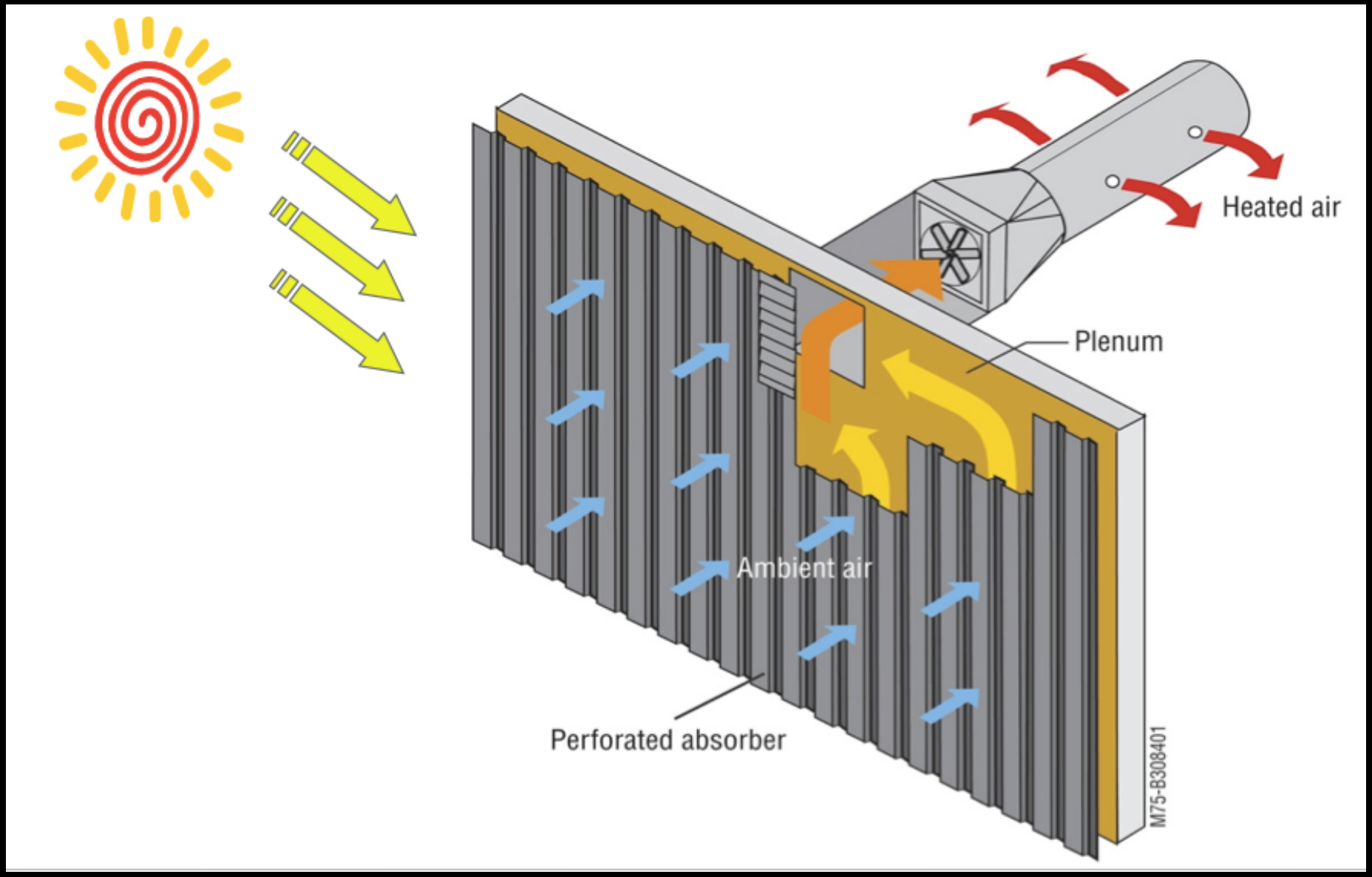

35 kBtu/SF-yr
$259/SF

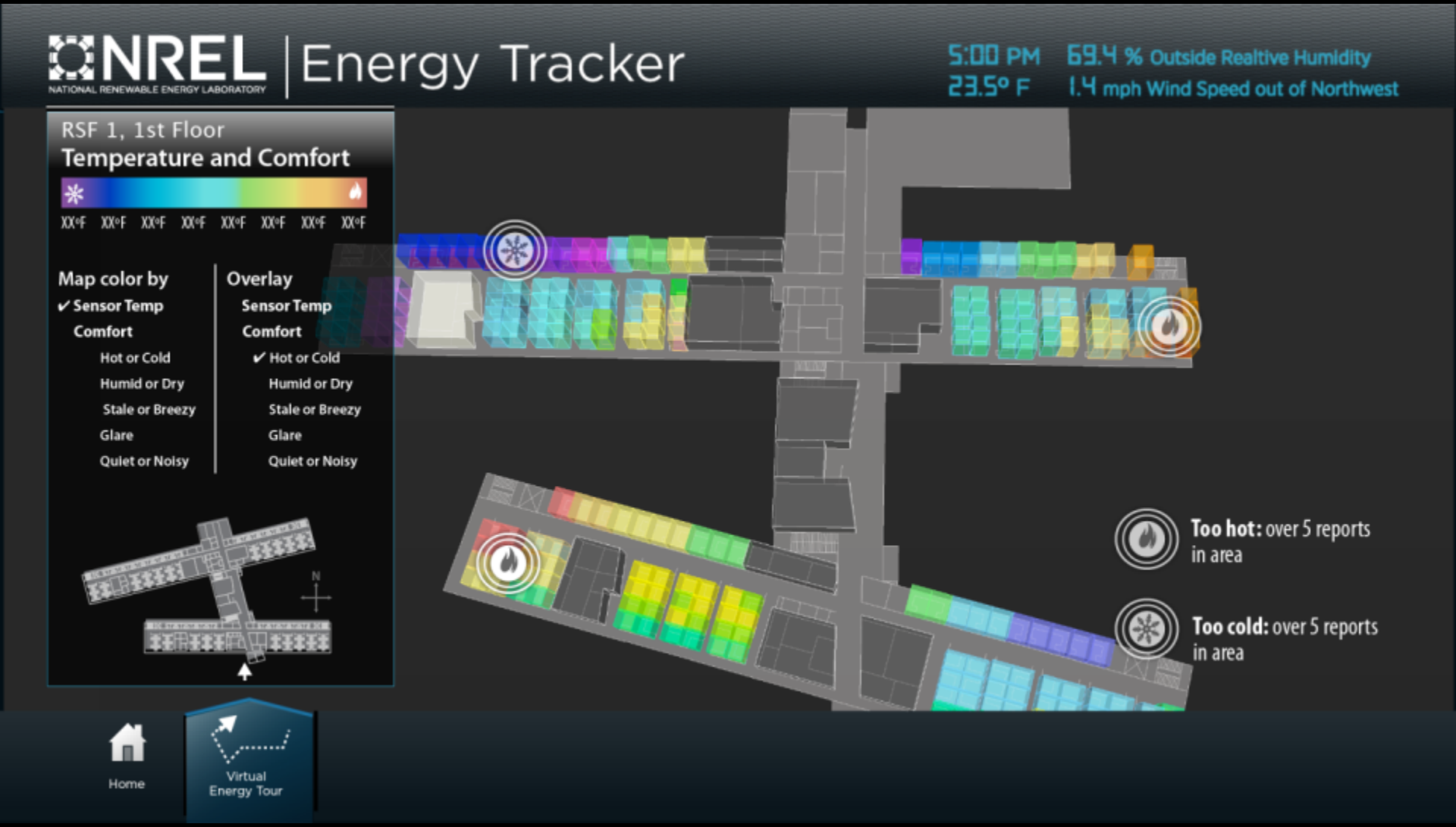

Radiant Ceilings
Underfloor Ventilation
Thermal Mass Walls
Operable Windows


Ambient daylight
Ambient lighting with daylight sensors for 25 fc
6 watt task light 50 fc


Typical
Workstation
400 Watts
RSF
Workstation
70 Watts

Transpired Collector Vent Preheat




NREL
NATIONAL RENEWABLE ENERGY LABORATORY
Energy Tracker
5:00 PM
23.5° F
69.4 % Outside Realtive Humidity
1.4 mph Wind Speed out of Northwest
RSF 1, 1st Floor
Temperature and Comfort
XX°F XX°F XX°F XX°F XX°F XX°F XX°F XX°F
Map color by
✓ Sensor Temp
Comfort
Hot or Cold
Humid or Dry
Stale or Breezy
Glare
Quiet or Noisy
Overlay
Sensor Temp
Comfort
✓ Hot or Cold
Humid or Dry
Stale or Breezy
Glare
Quiet or Noisy
N
Too hot: over 5 reports in area
Too cold: over 5 reports in area
Home
Virtual Energy Tour

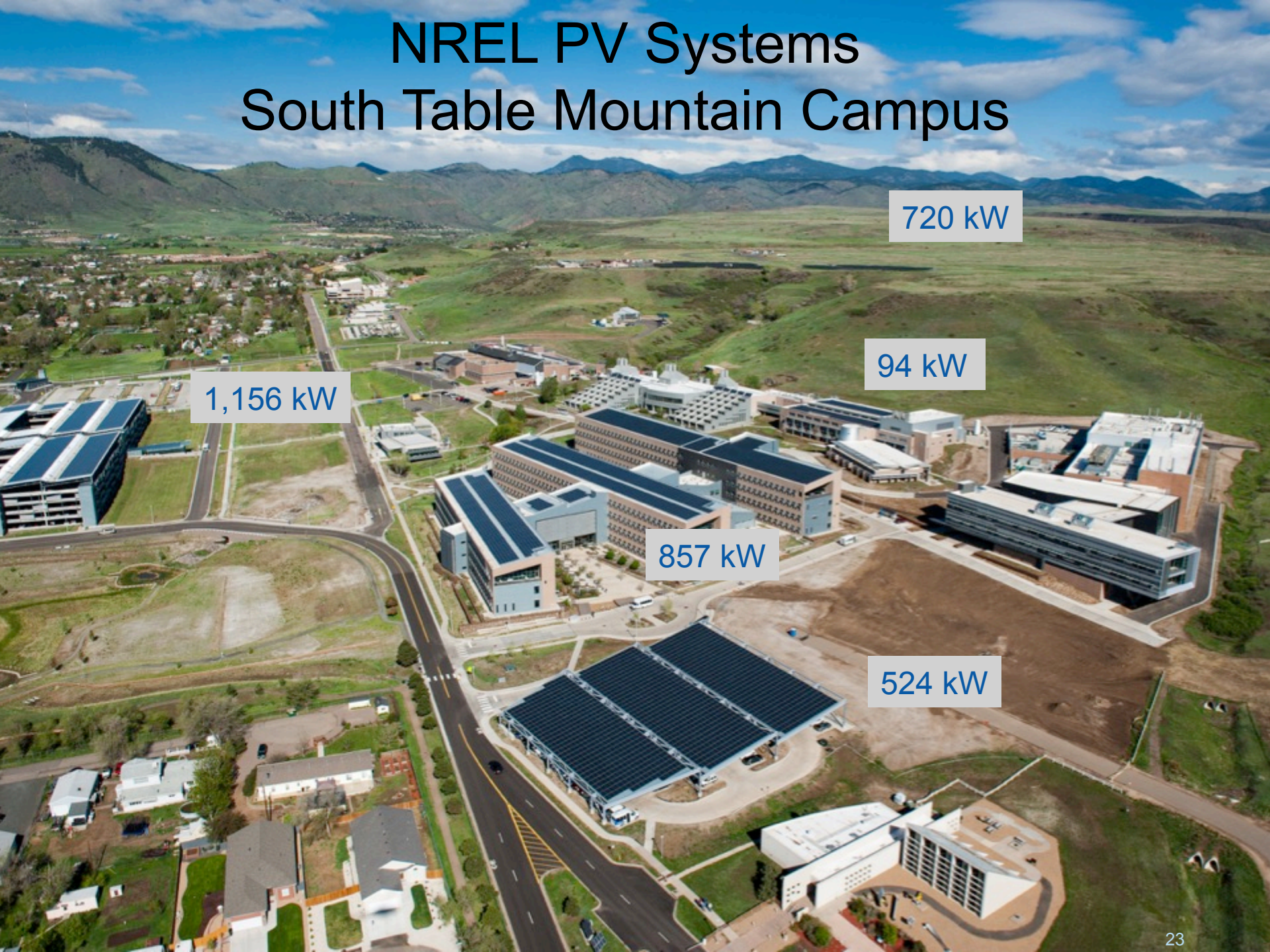
Buildings Powered by Renewable Electricity

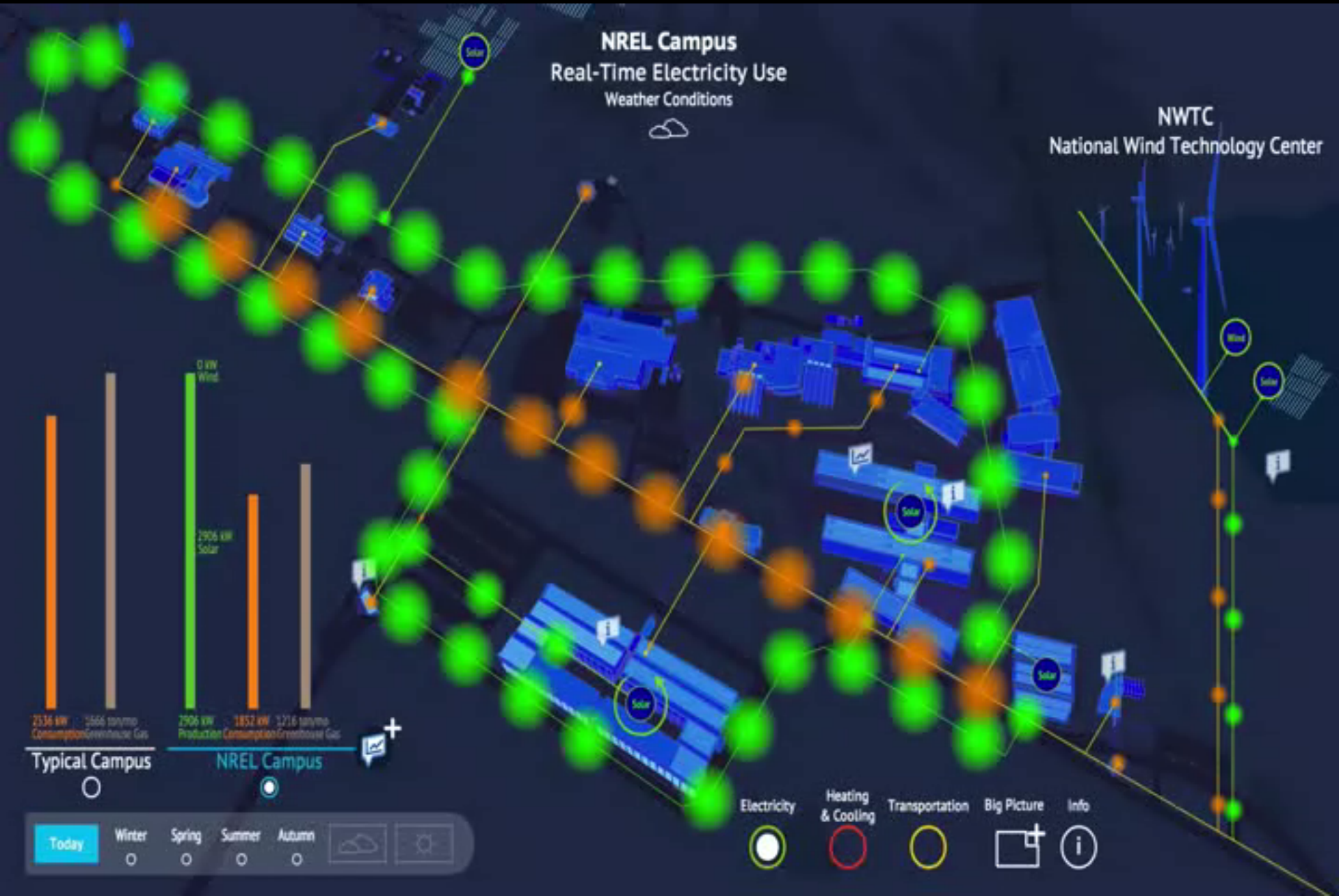
U.S. Electricity Consumed by Buildings

74%

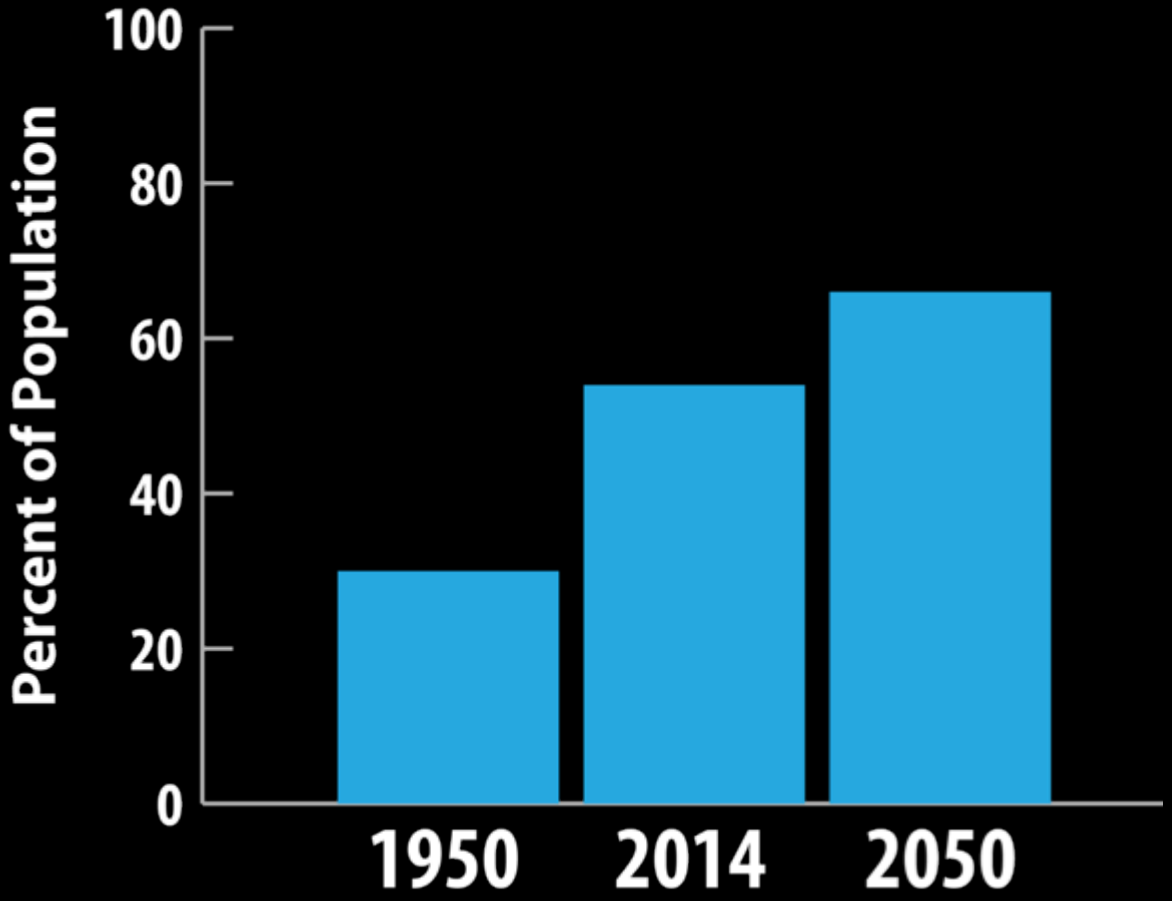
U.S. Energy Information Administration

NREL PV Systems
South Table Mountain Campus




NREL Campus
Real-Time Electricity Use
Weather Conditions
NWTC
National Wind Technology Center
0 kW Wind
2906 kW Solar
2536 kW Consumption
5666 tons/mo Greenhouse Gas
2906 kW Production
1852 kW Consumption
1216 tons/mo Greenhouse Gas
Typical Campus
NREL Campus
Today
Winter
Spring
Summer
Autumn
Electricity
Heating & Cooling
Transportation
Big Picture
Info

The World's Population is Shifting to Urban Areas:



North America 2014: **82%**

Source: UN http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf

Cities are responsible for

70%

of the world's fossil fuel CO_2 emissions

Source: Cities and Climate Change: an urgent agenda, World Bank, 2010

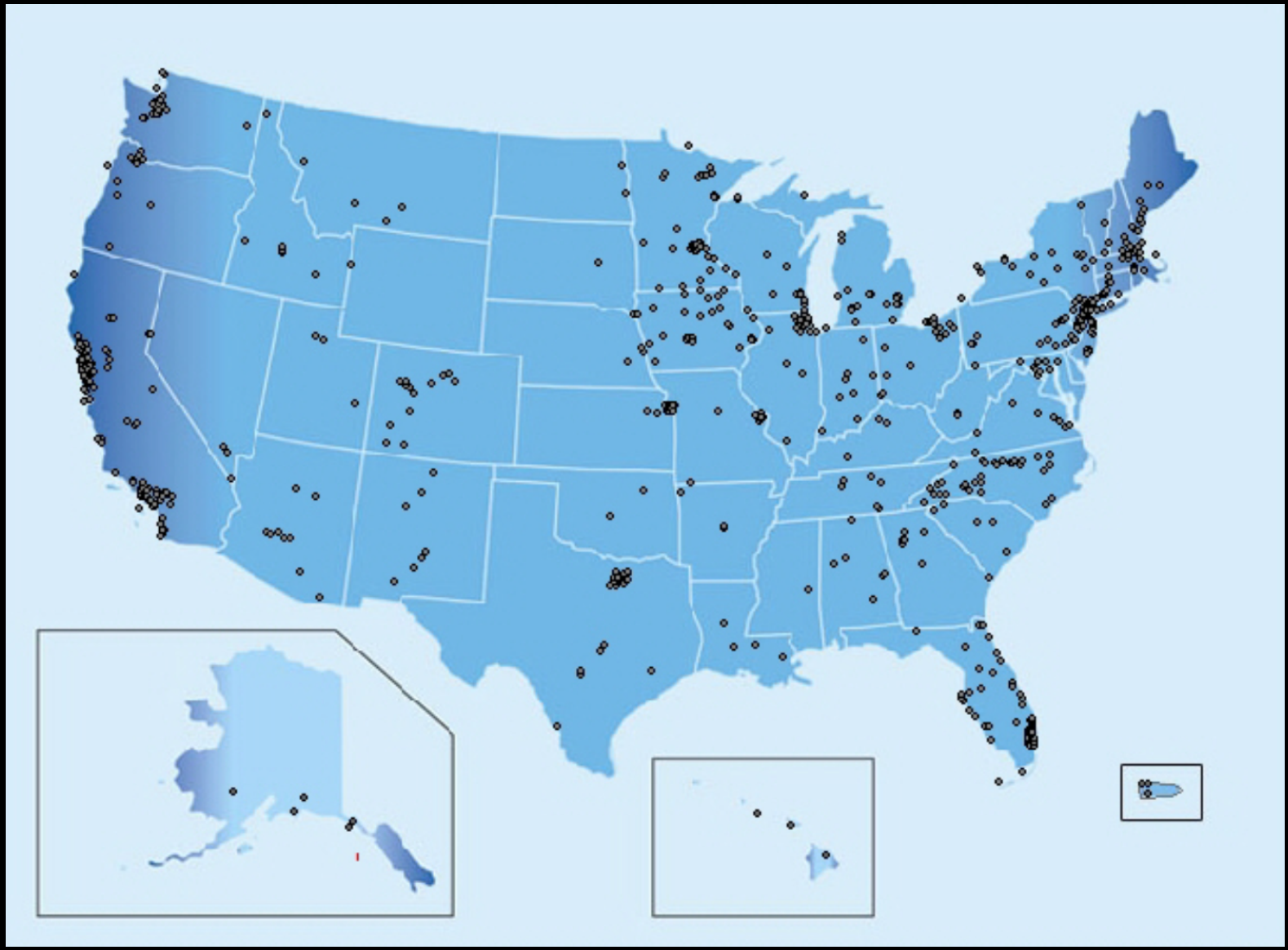
Image: NASA

By 2030

900 billion ft^2

of new and rebuilt buildings will be constructed worldwide

Sources:
UN Habitat, *State of the World's Cities 2010/2011*; McKinsey Global Institute.



Cities signed onto the Mayors' Climate Protection Agreement
1,060 as of 8/19/15

High Performance Energy Districts: The Next Step in NREL Buildings Leadership

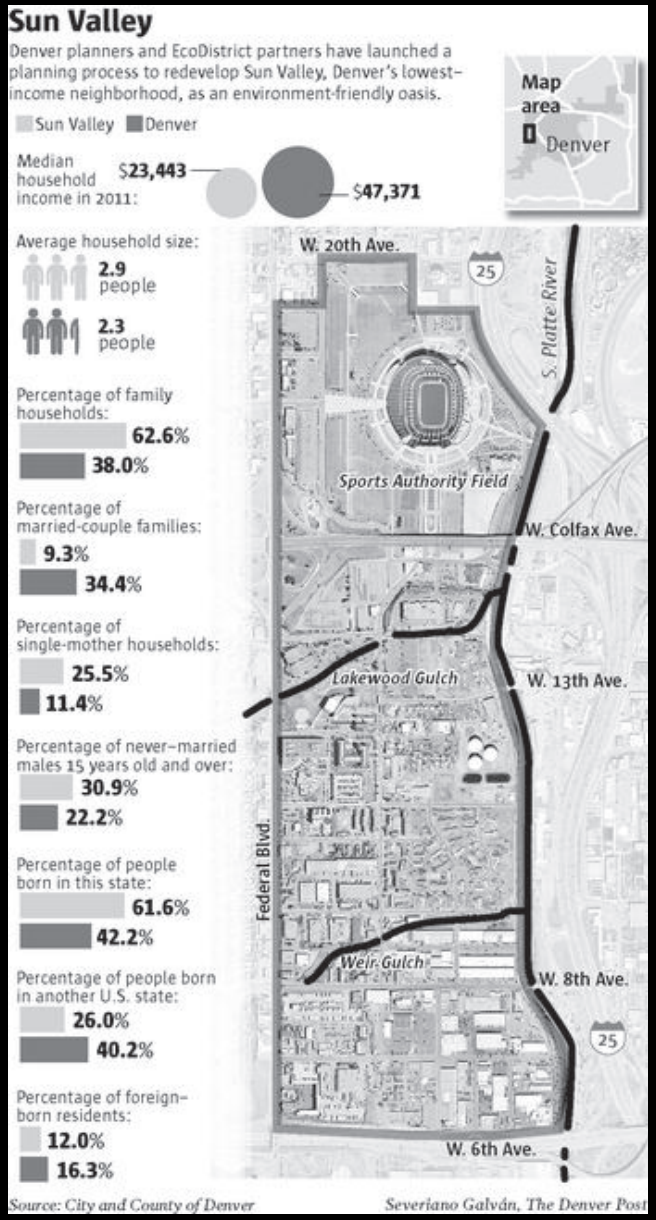
High-Performance Buildings

High-Performance Urban Districts

Denver National Western Center

- Redevelop 130 acres of the National Western Complex and Denver Coliseum sites
- Net zero district: energy, water, waste

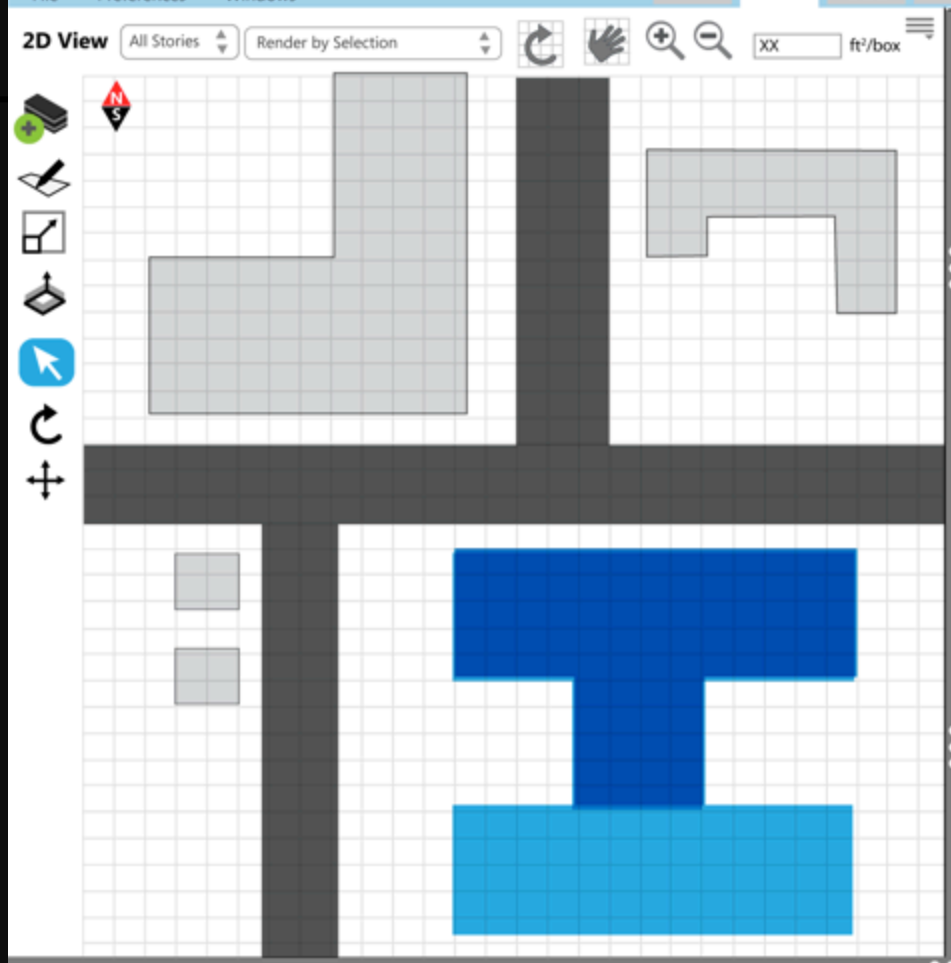
Denver Sun Valley Neighborhood



- Denver Housing Authority to demolish existing public housing, re-build at 3 times density
  - 1/3 public housing, 1/3 low-income, 1/3 market rate

URBANopt • name_of_the_project_here

File Preferences Windows

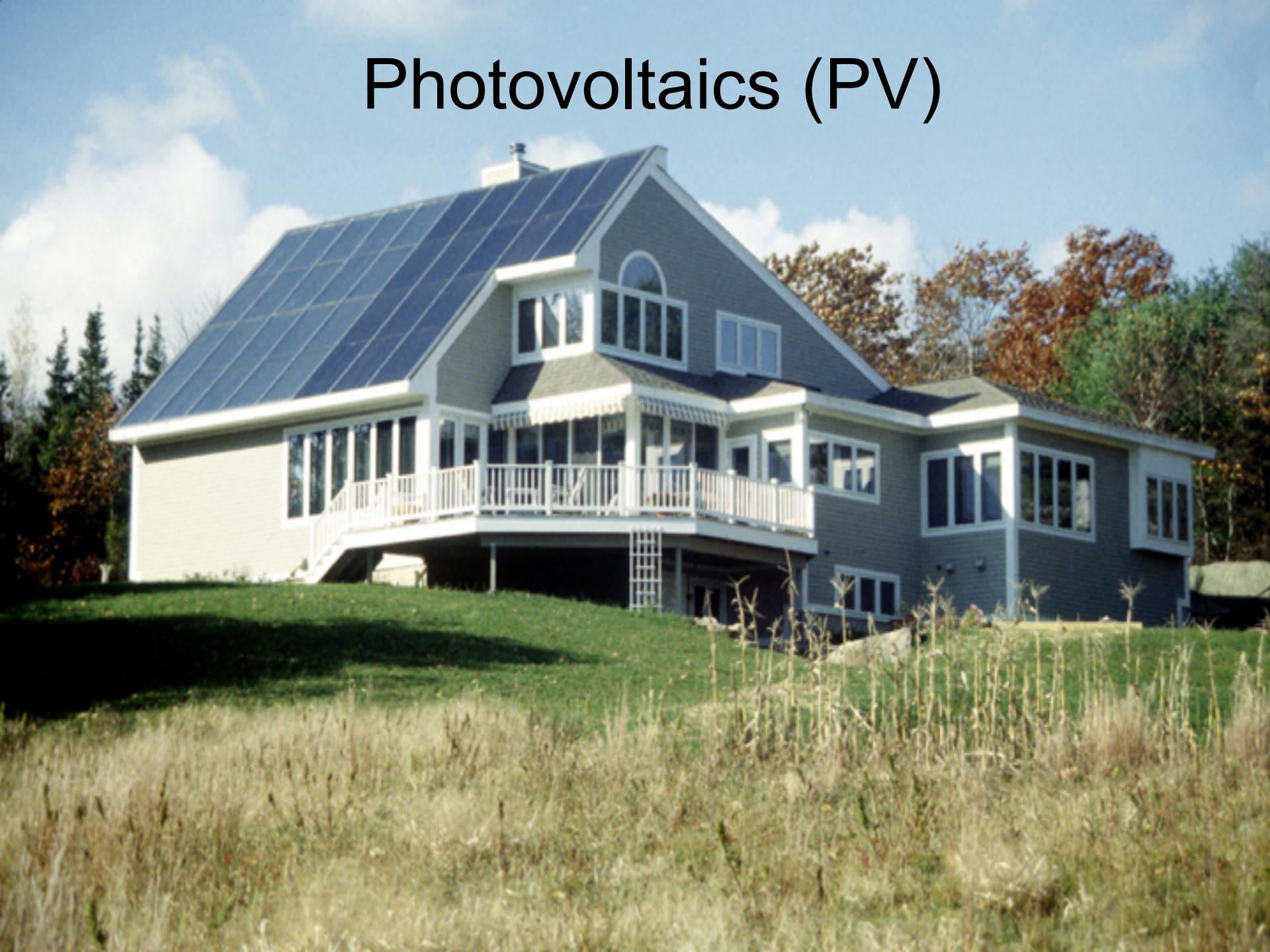


Edit and Add Buildings | Energy Estimates

Building Name		Electricity			Natural Gas			Heating & Cooling Jan–Dec	Total							Solar PV Potential		
Electrnics Superstore	1 Stories	kWh	tCO_2	$	therms	tCO_2	$		MMBTU	Site EUI	Peak Demand (kW)	% Electricity	% Gas	Carbon	$	Installed W	$/W	Cost
Baseline Standard	50% Savings Above Code	307,200	215	24,576	1,536	10	1,666		1,202	32	104	73	27	226	26,242	15,000	2.50	450,00
Alternatives (2)	30% Savings Above Code	384,000	269	30,720	1,920	13	2,083		1,502	40	130	73	27	282	32,803	0	2.50	0
	Net Zero	253,400	162	15,000	1,152	8	1,250		901	24	78	73	27	250	19,681	30,000	2.50	900,00
Parkplace Apartments	3 Story	kWh	tCO_2	$	therms	tCO_2	$		MMBTU	Site EUI	Peak Demand (kW)	% Electricity	% Gas	Carbon	$	Installed W	$/W	Cost
Baseline Standard	50% Savings Above Code	150,290	106	10,736	1,357	9	9,952		2,330	33	150	70	30	240	20,682	0	0	0
Alternatives (1)	Net Zero	113,000	80	8,072	1,020	7	7,483		1,400	19.4	100	70	30	200	15,550	15,000	2.50	450,00

Export Hourly Load Profile for Selected

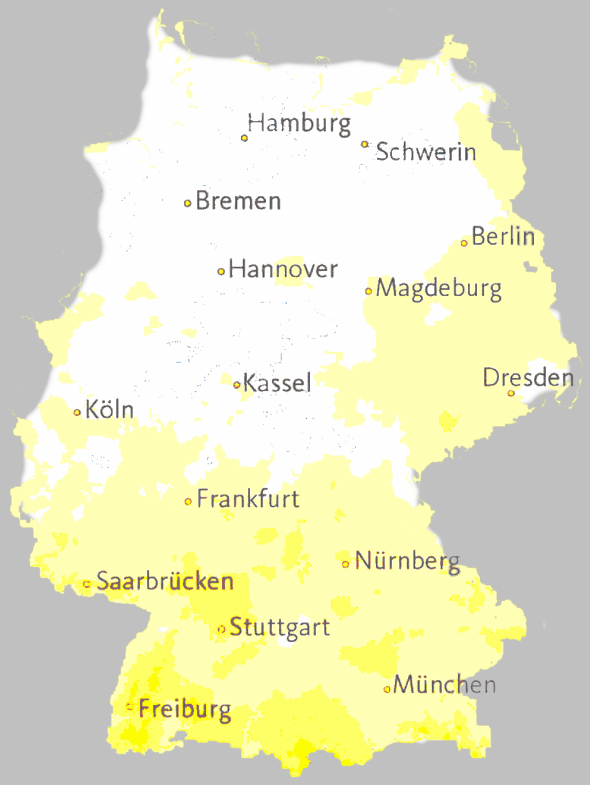
Photovoltaics (PV)

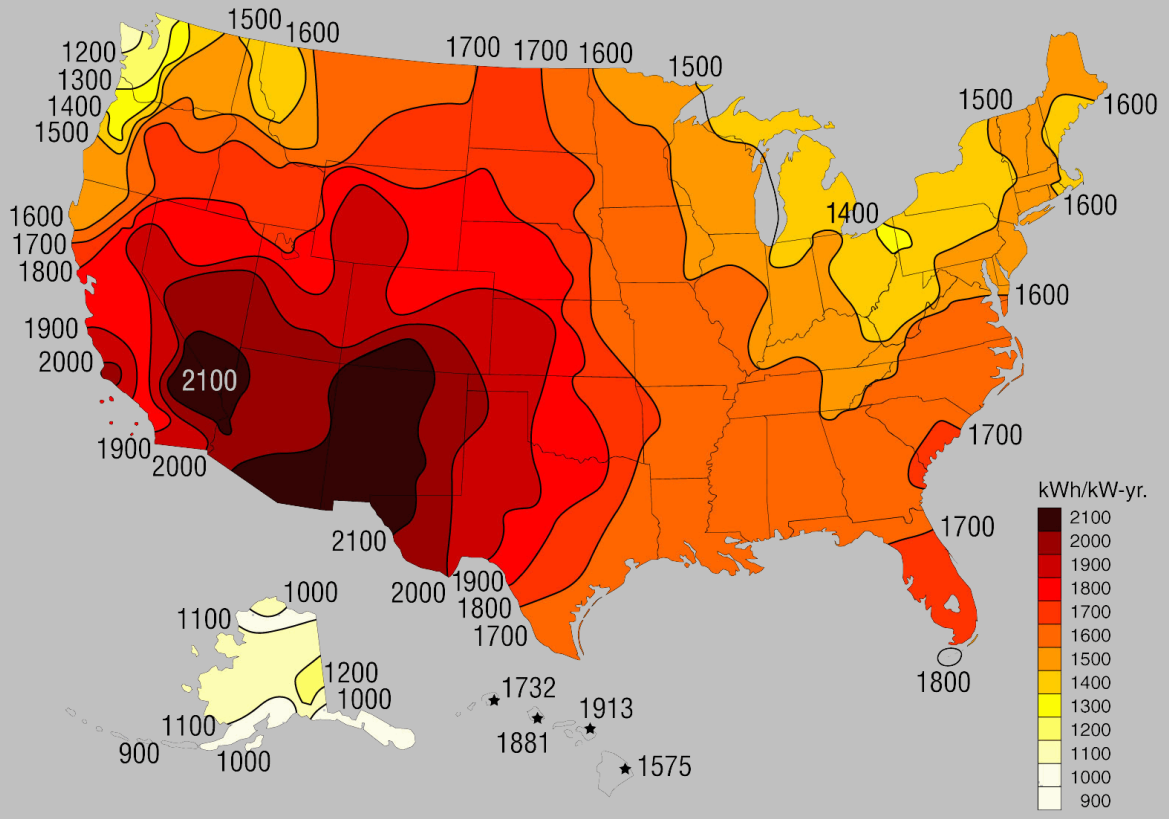


Germany sets solar record, meets half of electricity demand

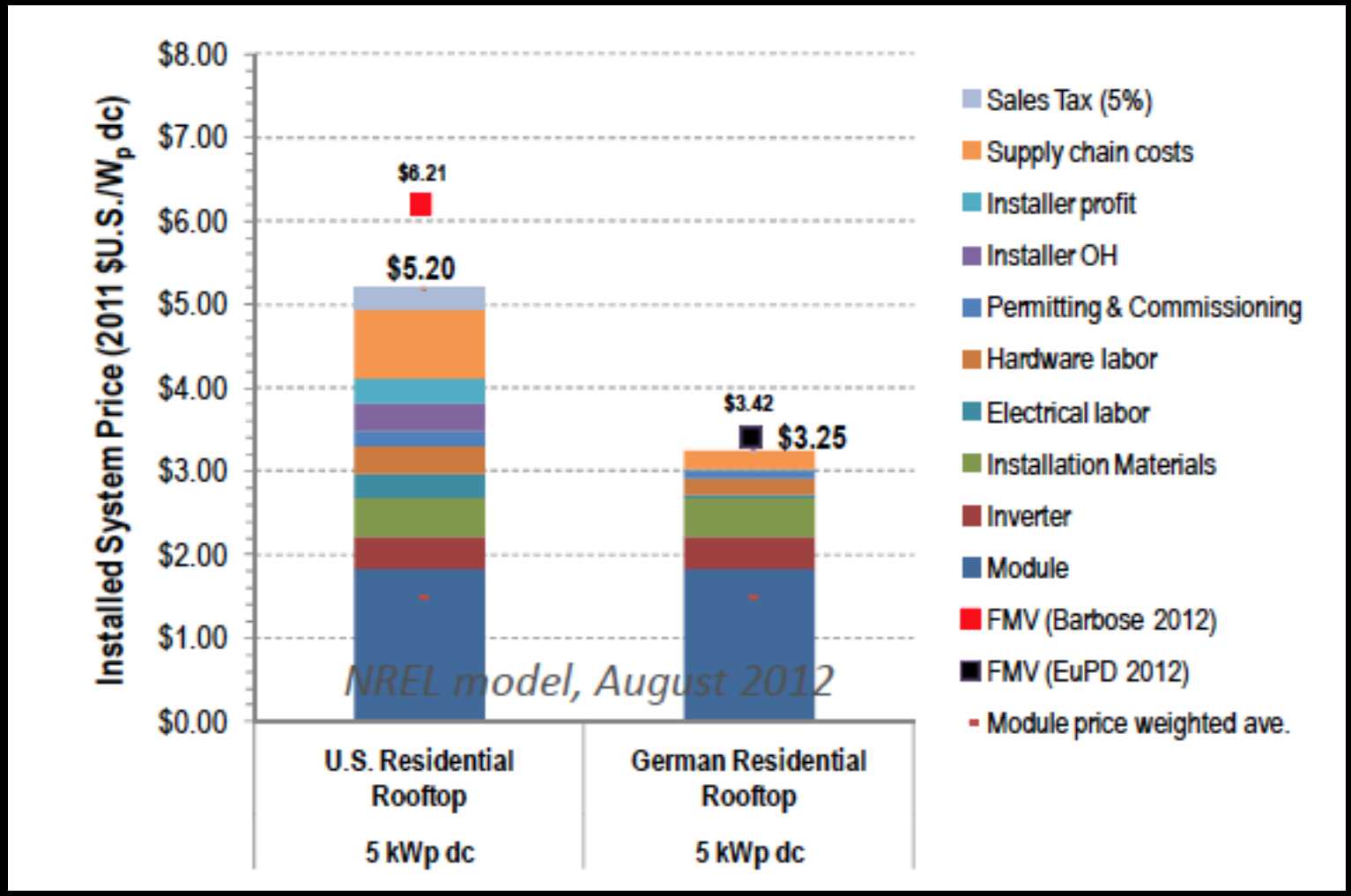
By Ian Steadman | 28 May 12

PV Resource: Germany vs. U.S.



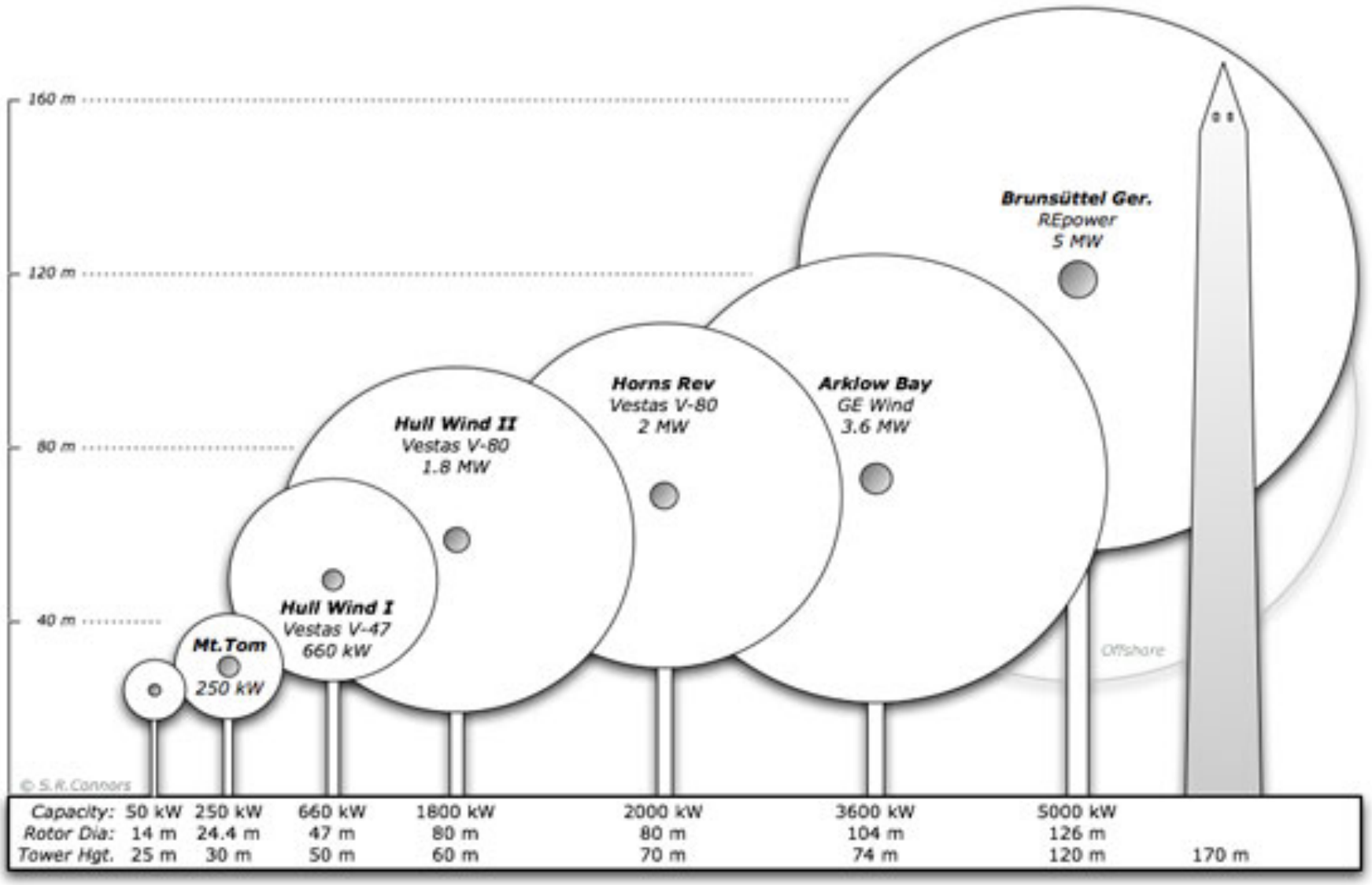


PV Cost Breakdown: US vs. Germany

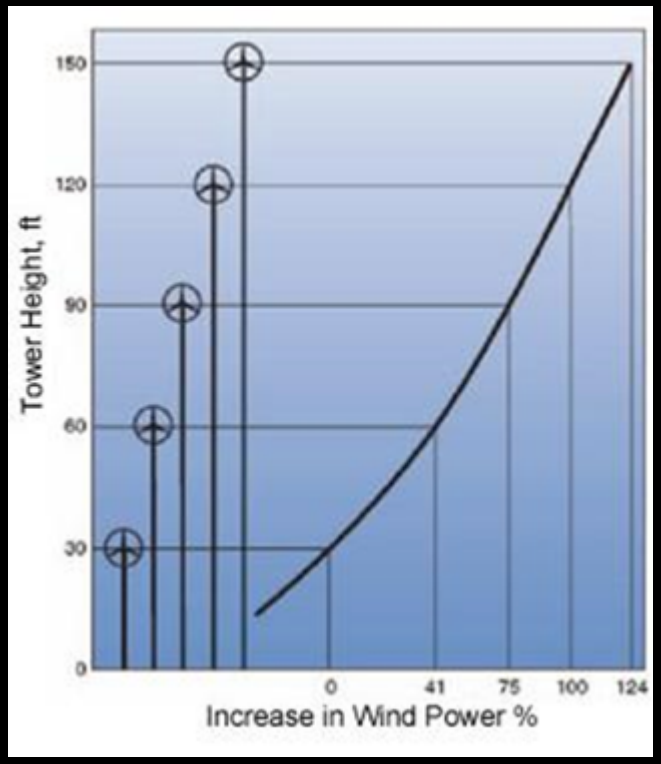


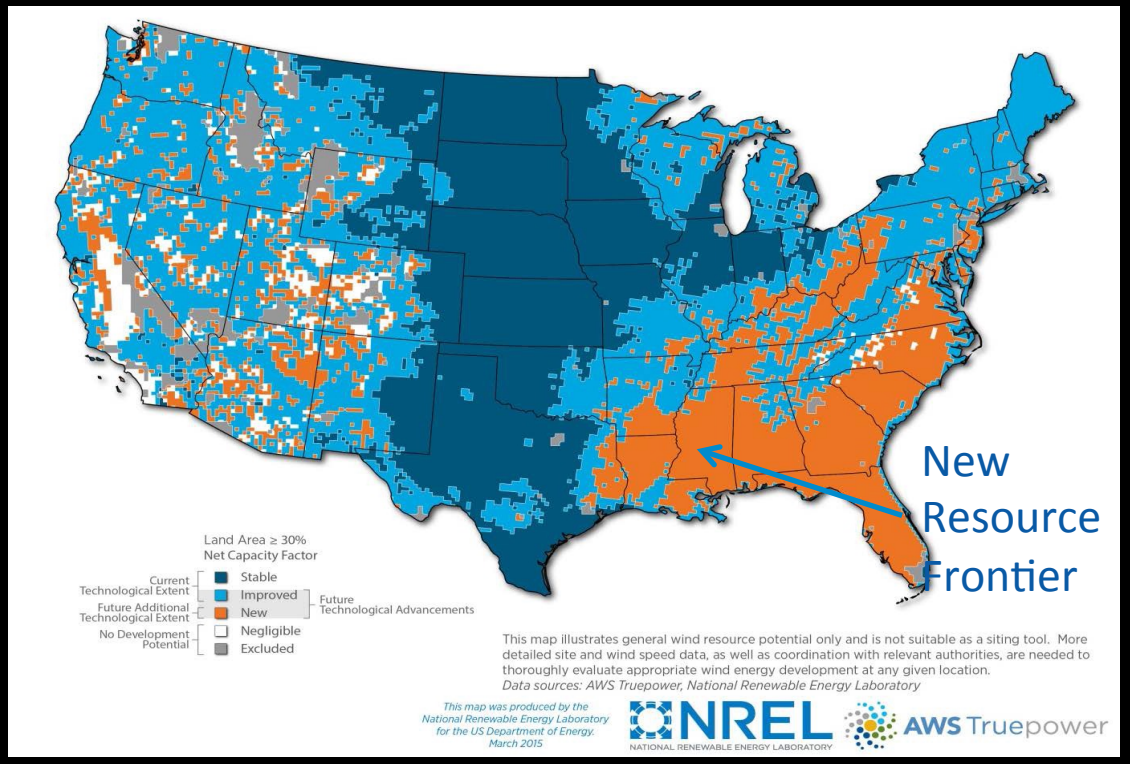
Wind

Wind Turbine Size



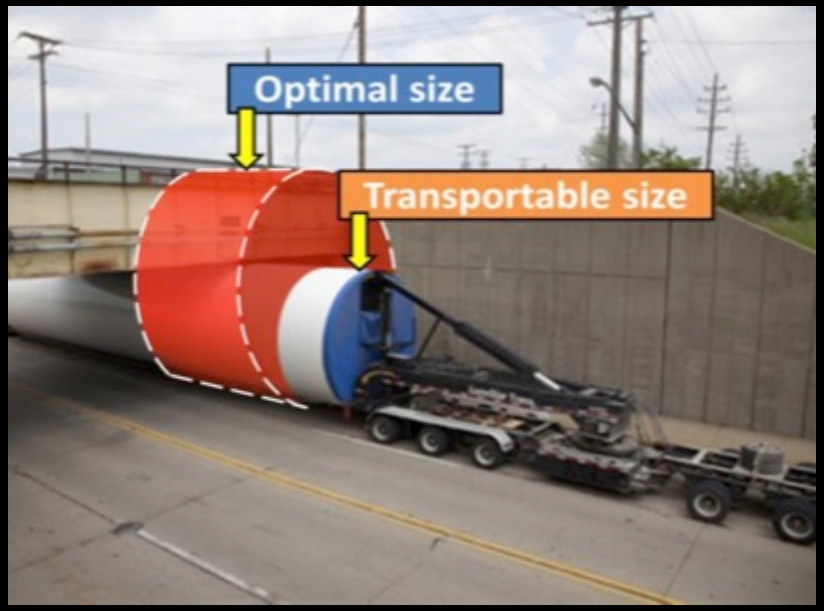
Tall Towers Above 120 m Can Open up to 2000 GW of Land-based Wind in Southeastern US





U.S. DOE (2015) Zayas et al, "Enabling Wind Power Nationwide", May 2015
http://energy.gov/eere/wind/downloads/enabling-wind-power-nationwide

Transport of 81.5m blade

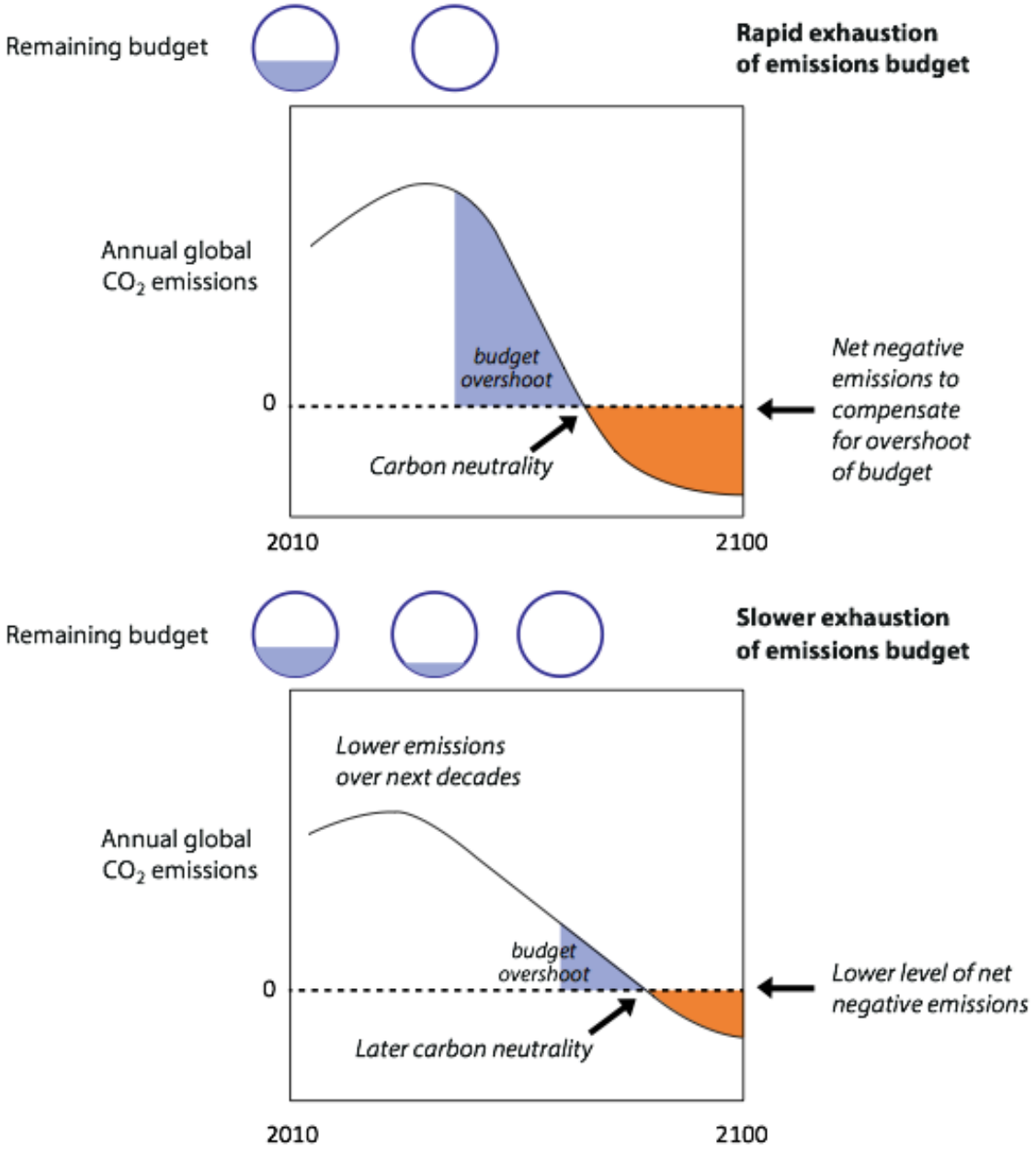


- Photo used by permission of Uni-Fly A/S

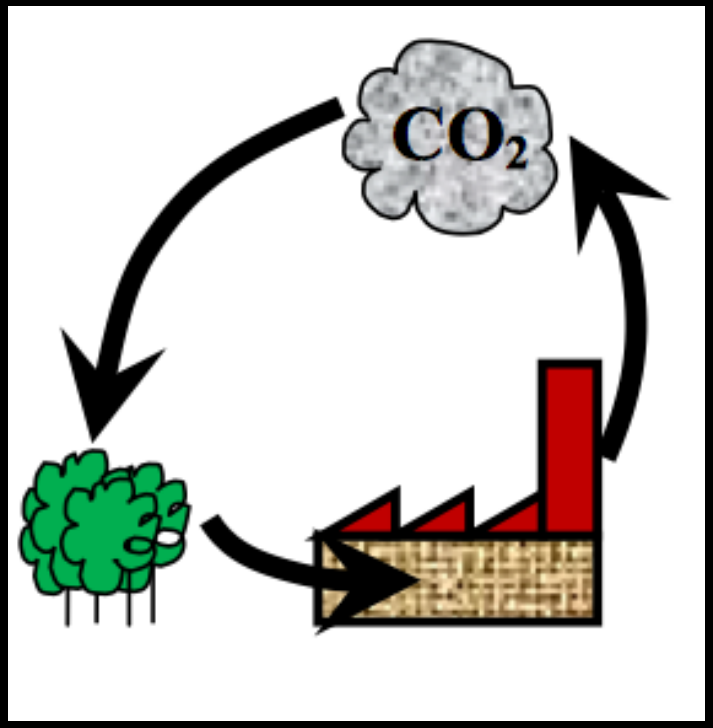
Concentrating Solar Power

250 MW Solana Plant with 6 hrs Storage

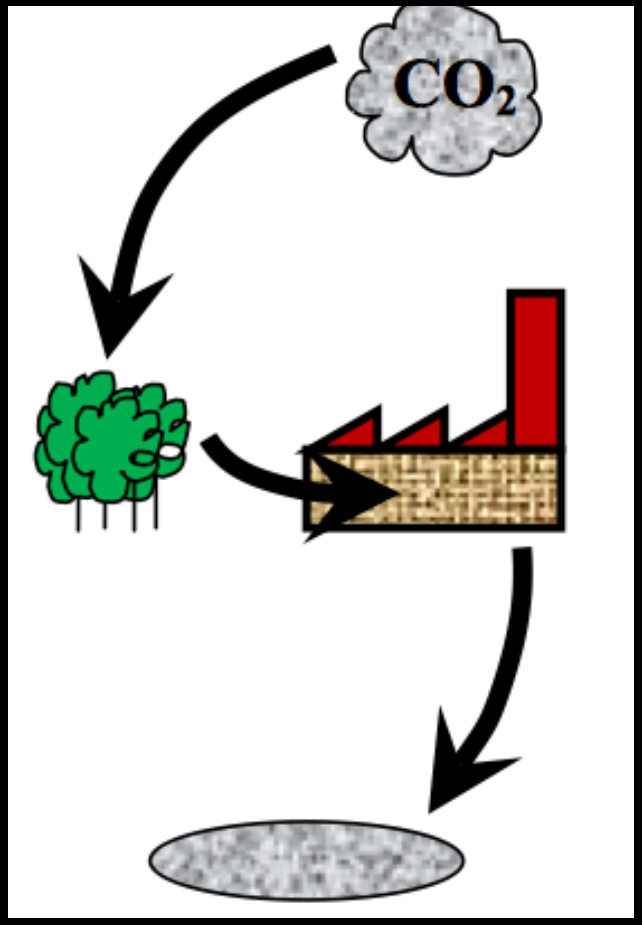
110-MW Crescent Dunes Plant with 10 hrs Storage


Remaining budget
Rapid exhaustion of emissions budget
Annual global CO_2 emissions
budget overshoot
0
Carbon neutrality
Net negative emissions to compensate for overshoot of budget
2010
2100
Remaining budget
Slower exhaustion of emissions budget
Lower emissions over next decades
Annual global CO_2 emissions
budget overshoot
0
Later carbon neutrality
Lower level of net negative emissions
2010
2100

BECCS



Conventional Biomass Power
Carbon Neutral



BECCS
Carbon Negative

Berkeley Western Region (WECC) BECCS Study

nature climate change

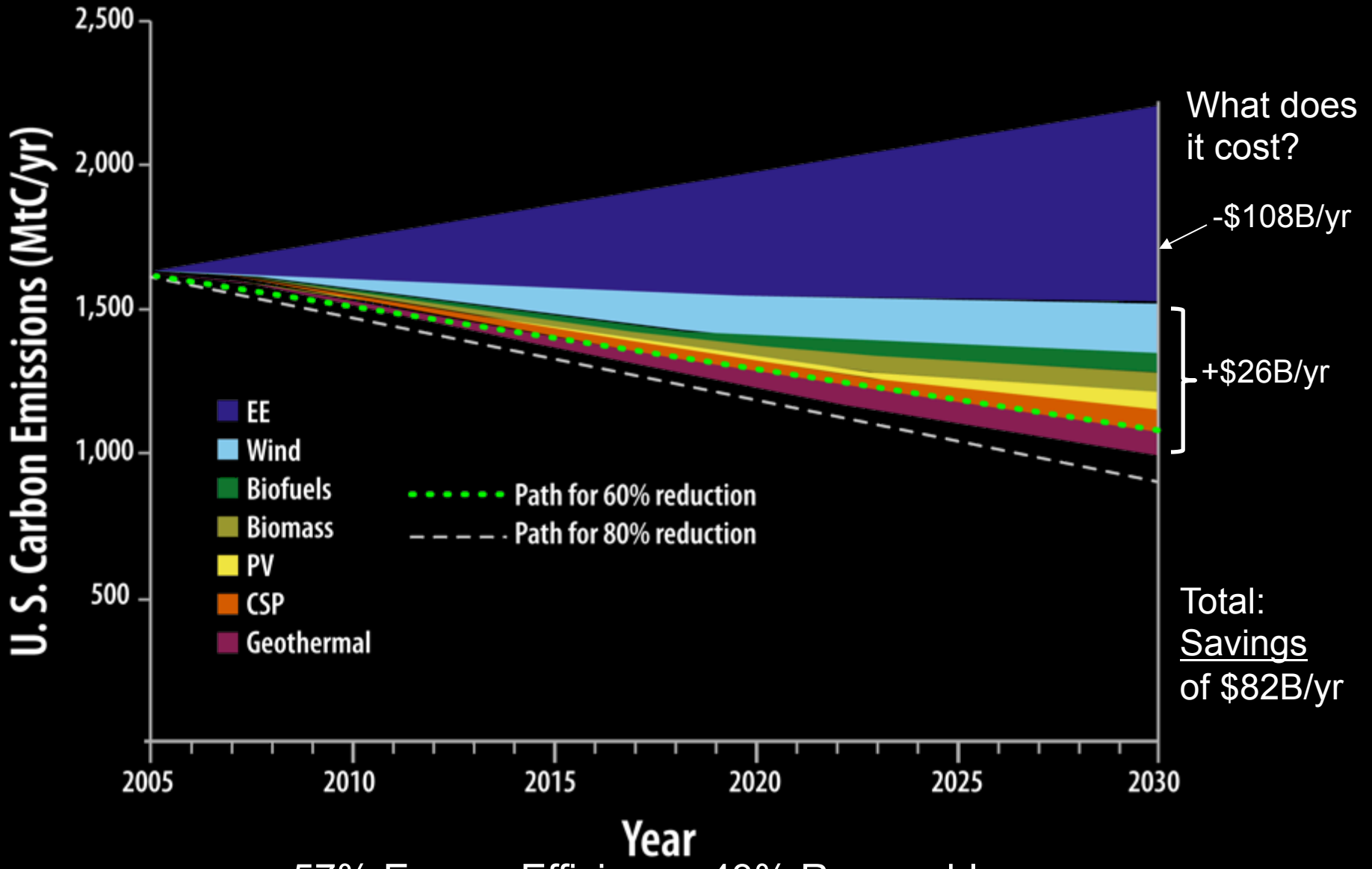
LETTERS

PUBLISHED ONLINE: 9 FEBRUARY 2015 | DOI: 10.1038/NCLIMATE2488

Biomass enables the transition to a carbon-negative power system across western North America

Daniel L. Sanchez[1], James H. Nelson[2], Josiah Johnston[1], Ana Mileva[1] and Daniel M. Kammen[1,3]*

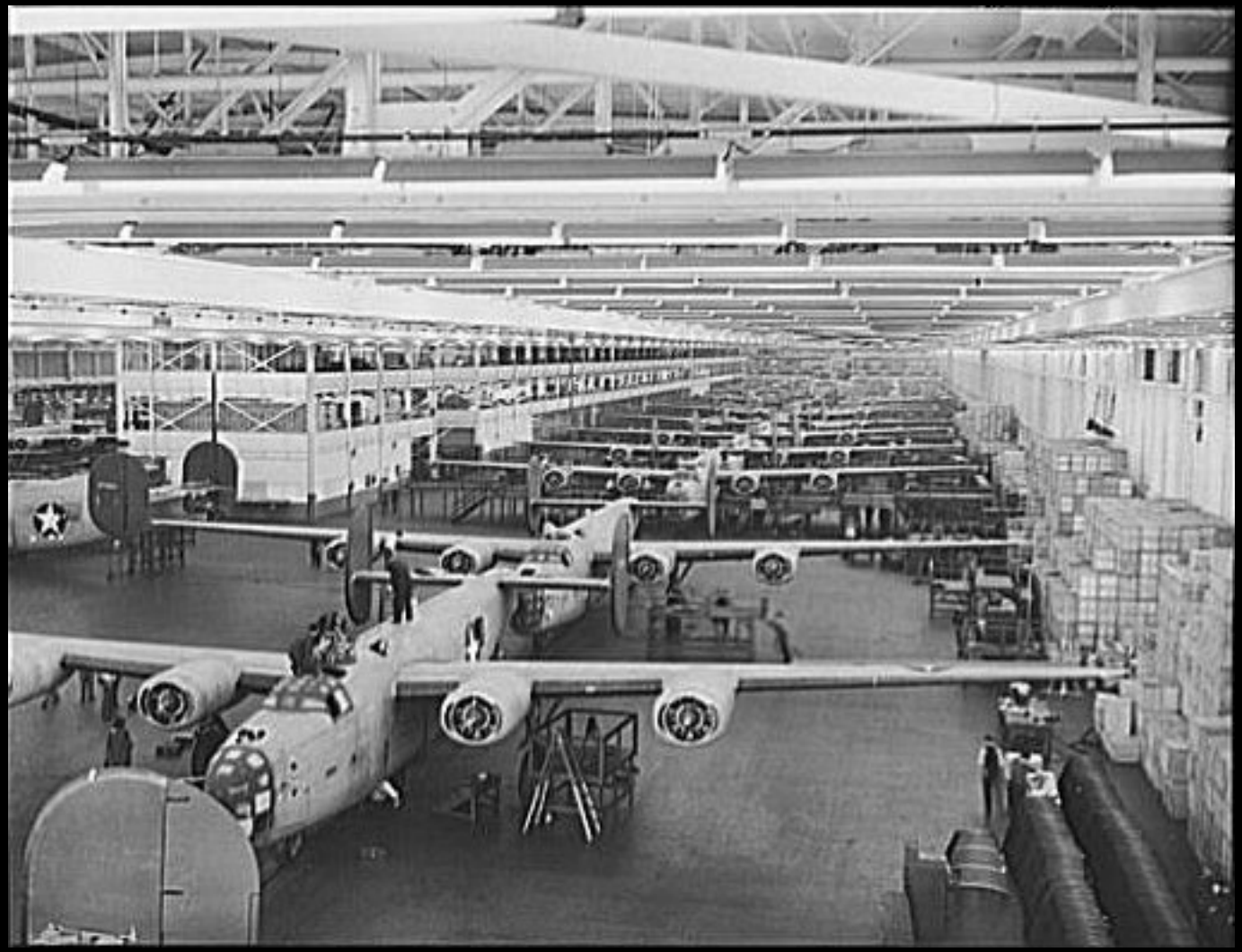
Potential U.S. Carbon Reductions



57% Energy Efficiency, 43% Renewables

Net Jobs Created: 4.5 million

Bezdek and Wendling, *International Journal of Global Wa*rming, Nov. 2014



1944: Ford Motor Company Willow Run, MI plant produced one B-24 bomber every 63 minutes, 24 hours/day, 7 days/week

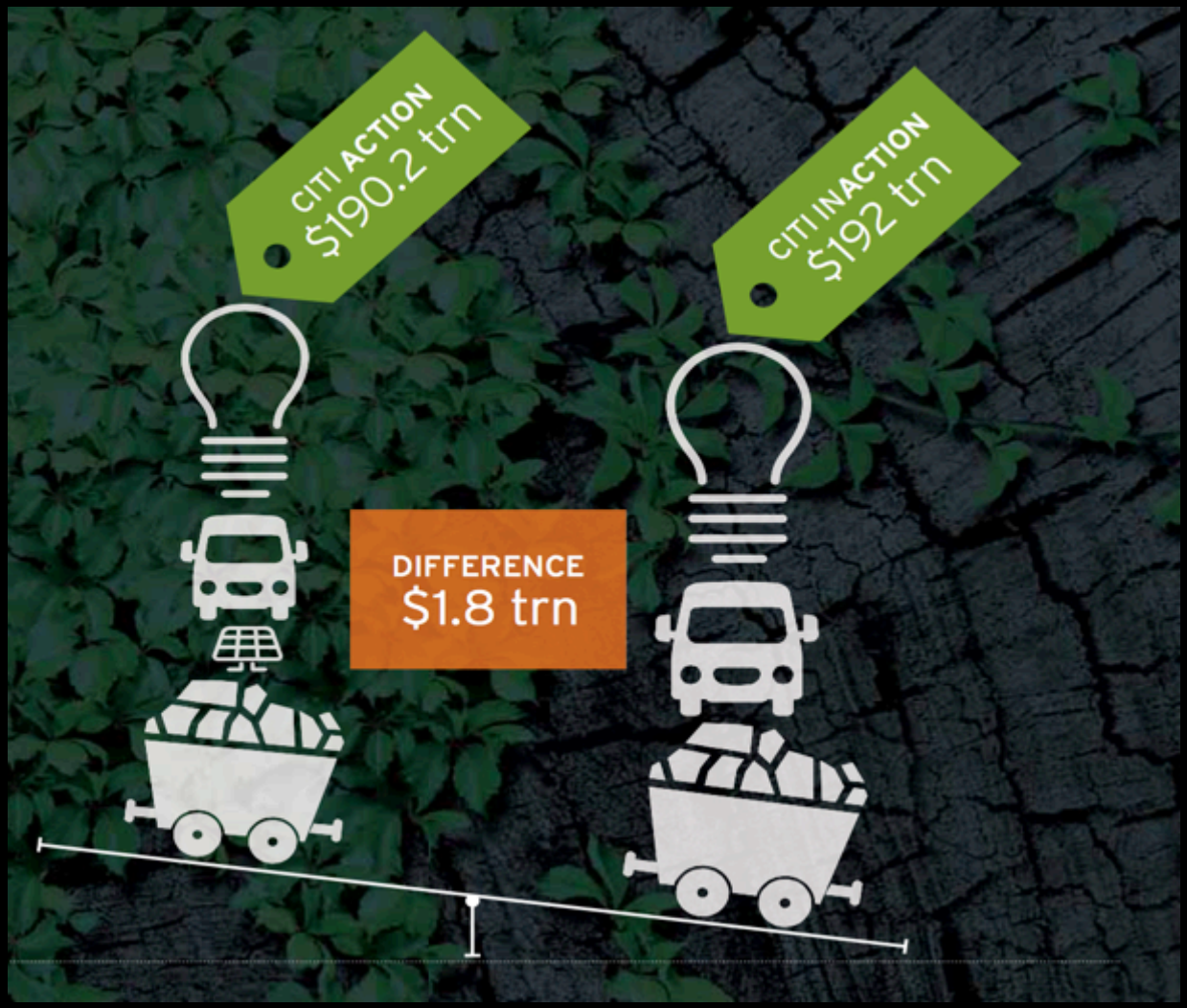
The Cost of Not Addressing Climate Change

Projected Cost to US
of Climate Change Damage
by Year 2025:

$271 Billion/yr

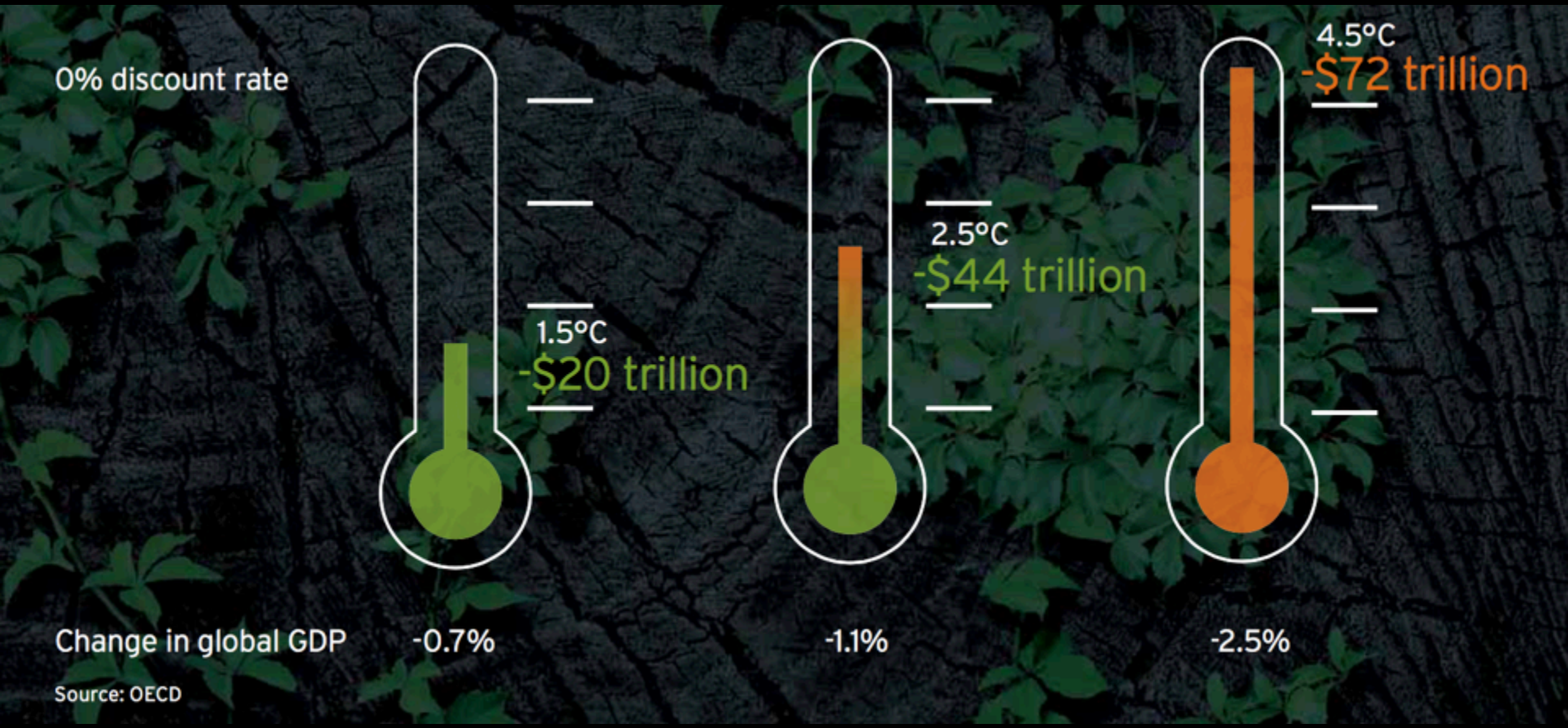
– Ackerman and Stanton, 2008

World Cost of Two Energy Approaches



Source: Citi Bank

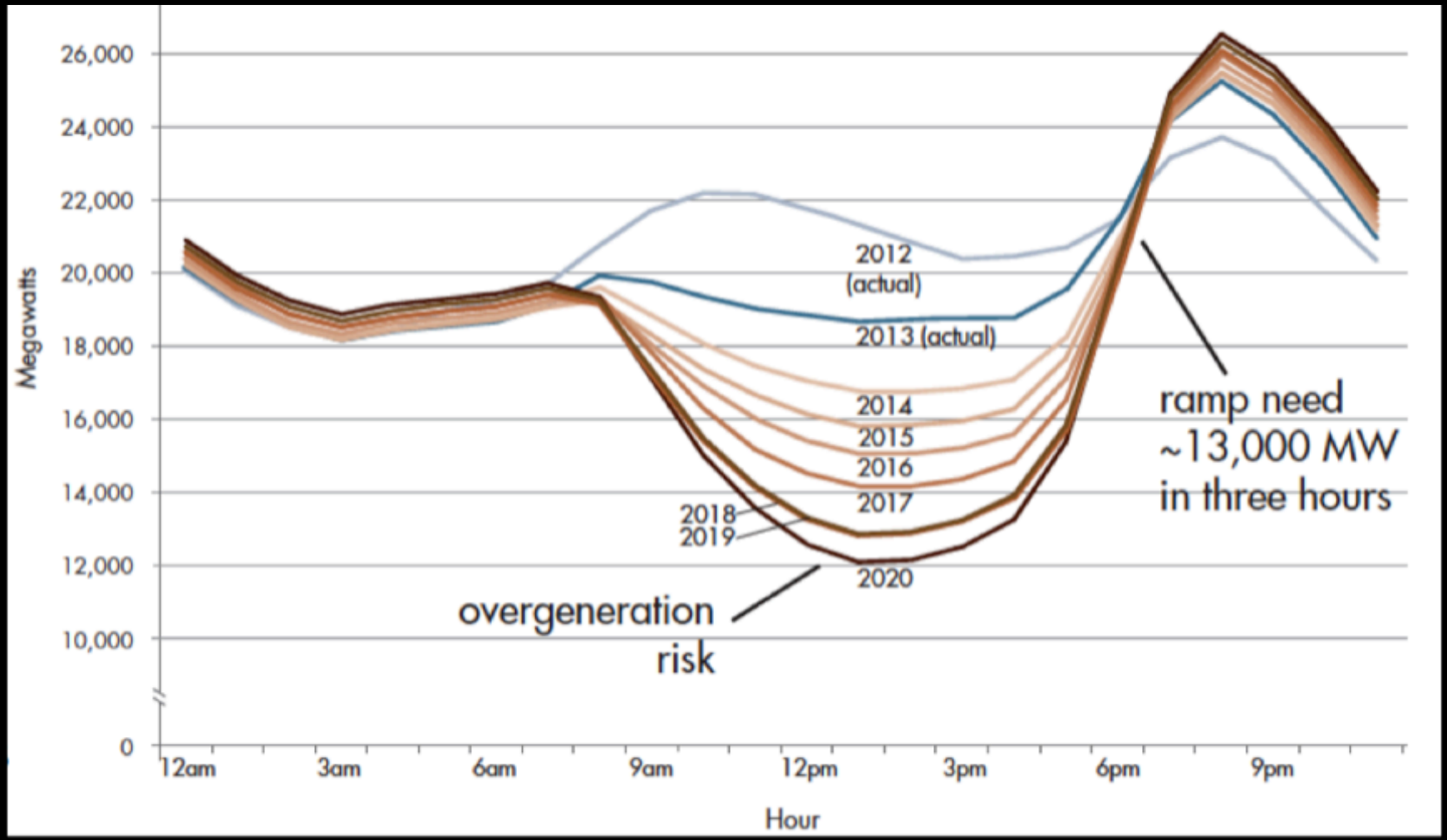
World Cost of Climate Change Damage (cumulative GDP)



Source: Citi Bank

The Grid Integration Challenge

“Duck” Curves


26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
0
Megawatts
12am
3am
6am
9am
12pm
3pm
6pm
9pm
Hour
2012 (actual)
2013 (actual)
2014
2015
2016
2017
2018
2019
2020
overgeneration risk
ramp need ~13,000 MW in three hours

Grid Integration Costs (Arizona Public Service)

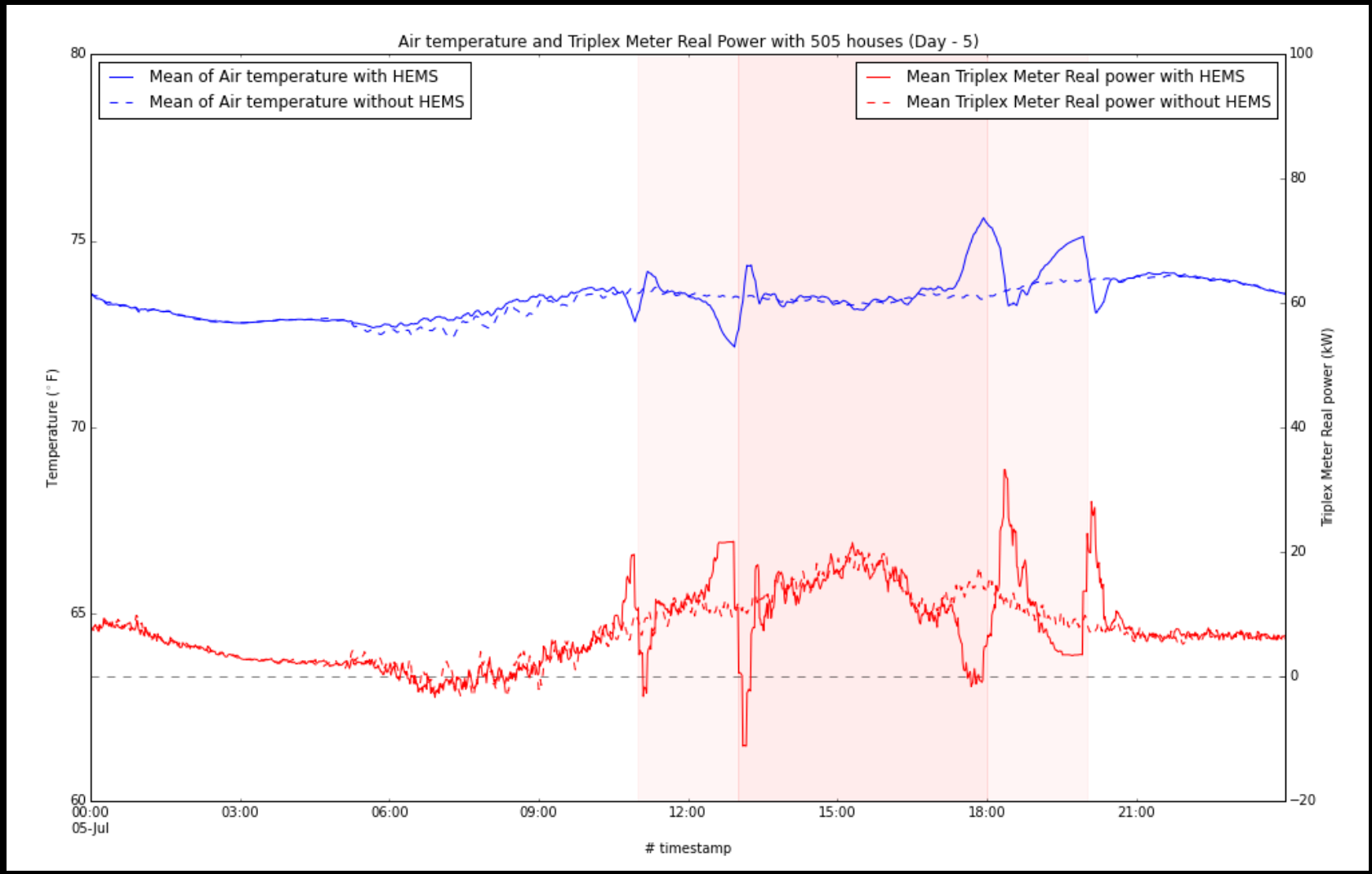
Wind Energy Penetration	1%	4%	7%	10%
Within-hour Regulating	$0.40	$0.41	$0.31	$0.37
Hour-ahead Uncertainty	$0.11	$1.88	$2.32	$2.65
Day-ahead Uncertainty	$0.39	$0.95	$0.93	$1.06

New NREL
Energy Systems Integration Facility

Distributed Solar – Distribution System Impacts

ESIF Smart Power Lab

Home Energy Management Impacts Grid

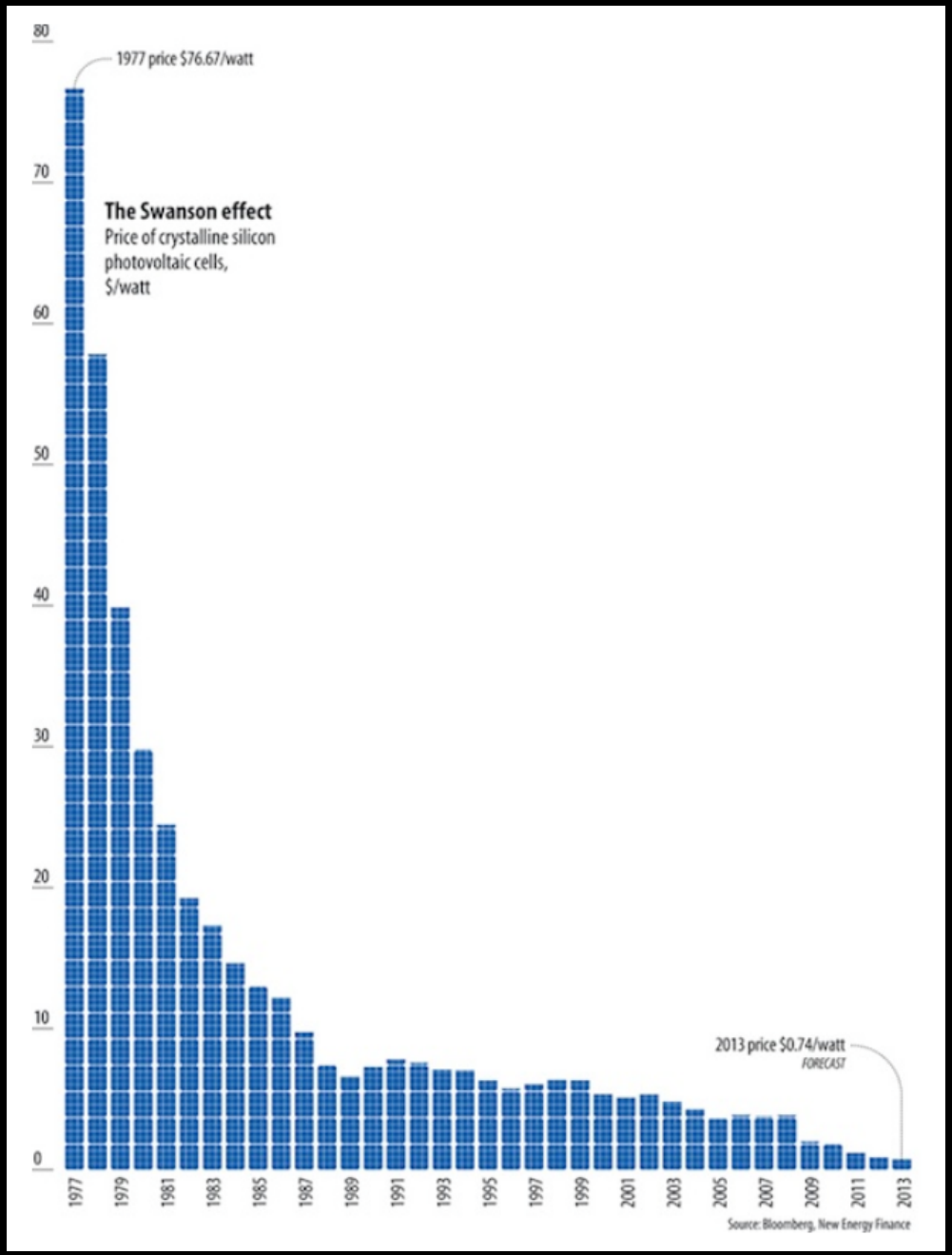


An enormous, disruptive transition is underway!

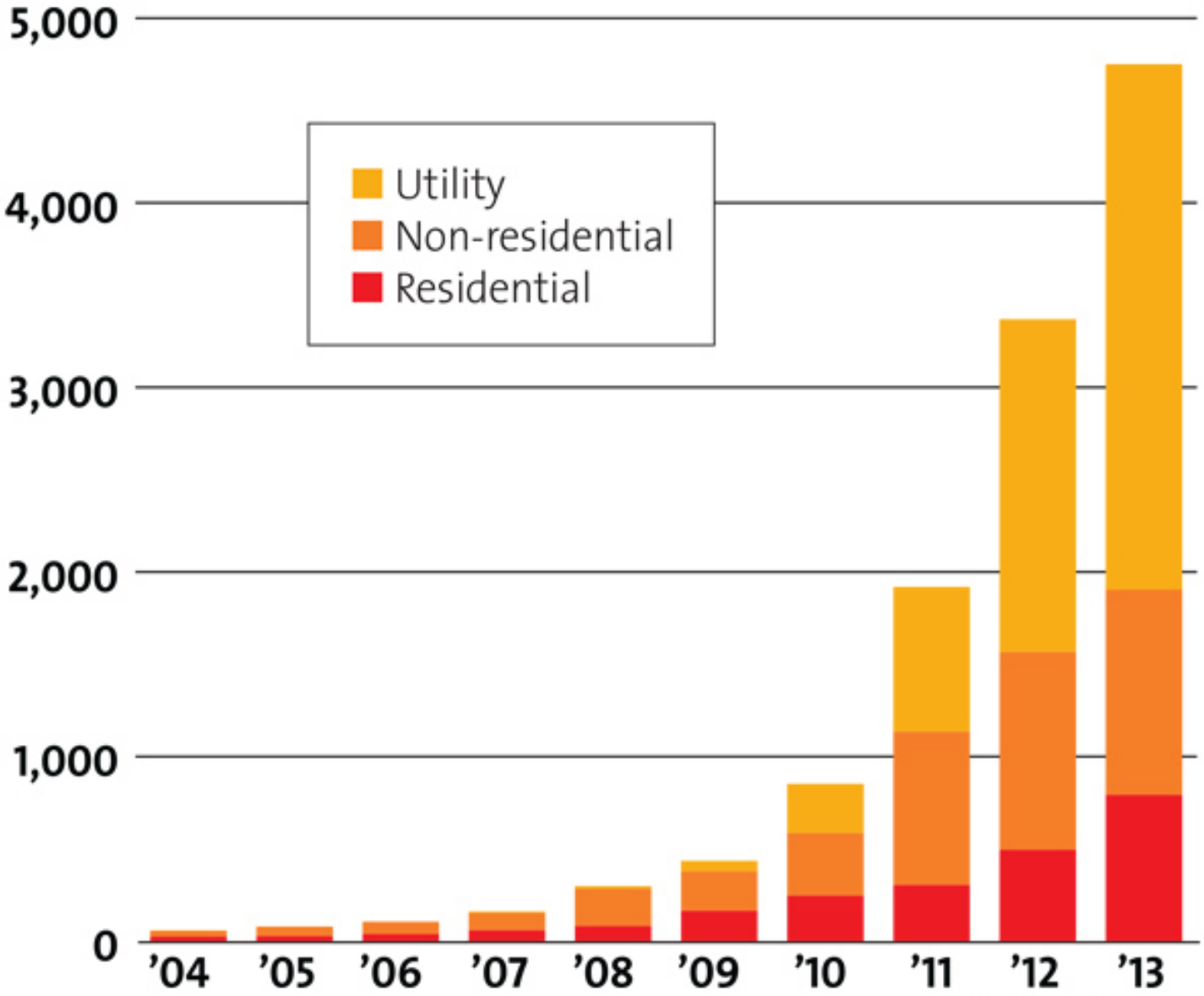
Early 20th Century:

Early 21st Century:

PV Module Prices



New solar installations in the United States (in megawatts)



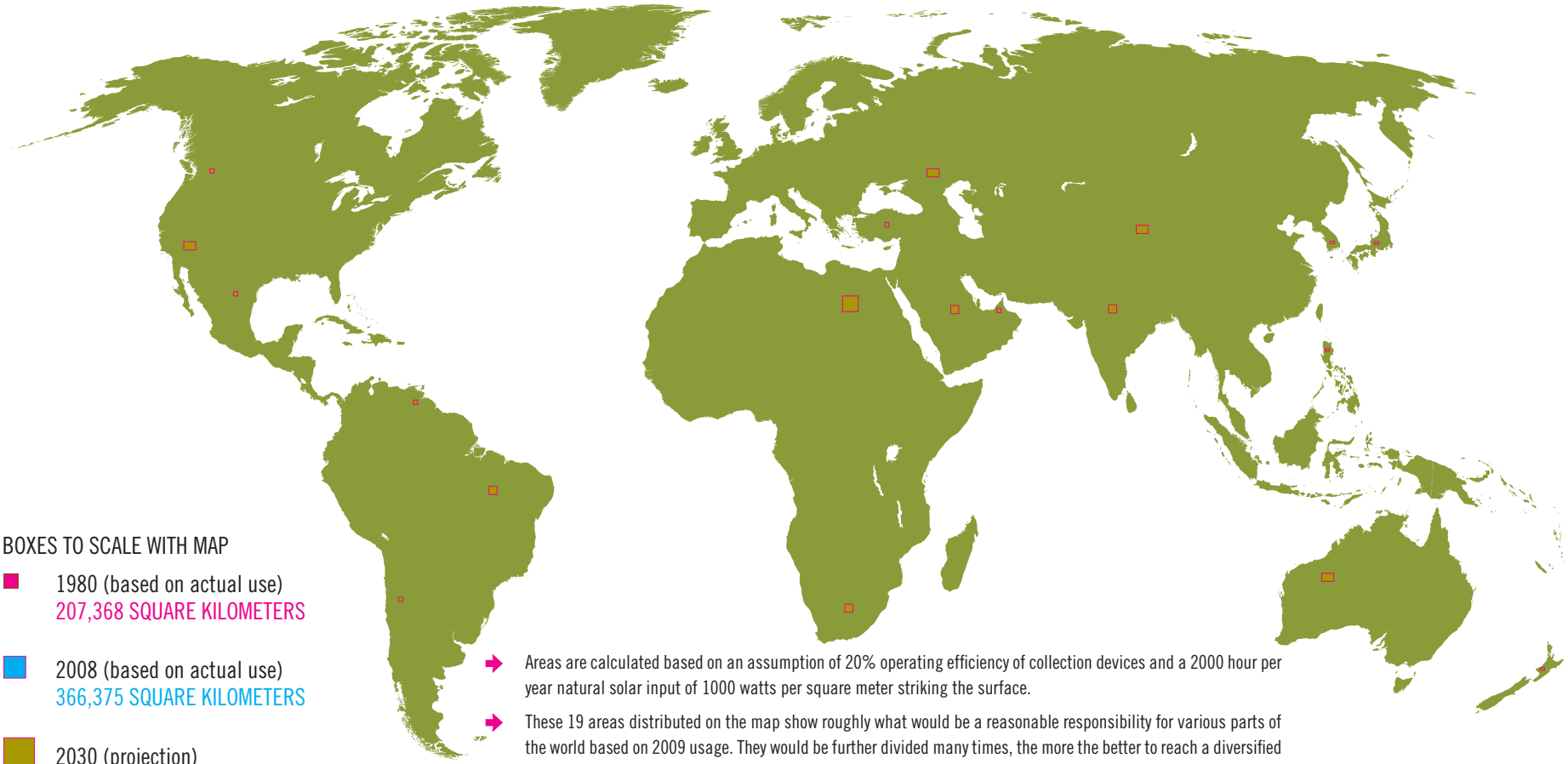
Source: SEIA

Mother Jones

SURFACE AREA REQUIRED TO POWER THE WORLD

WITH ZERO CARBON EMISSIONS AND WITH SOLAR ALONE

www.landartgenerator.org



BOXES TO SCALE WITH MAP

- 1980 (based on actual use)
  207,368 SQUARE KILOMETERS
- 2008 (based on actual use)
  366,375 SQUARE KILOMETERS
- 2030 (projection)
  496,805 SQUARE KILOMETERS

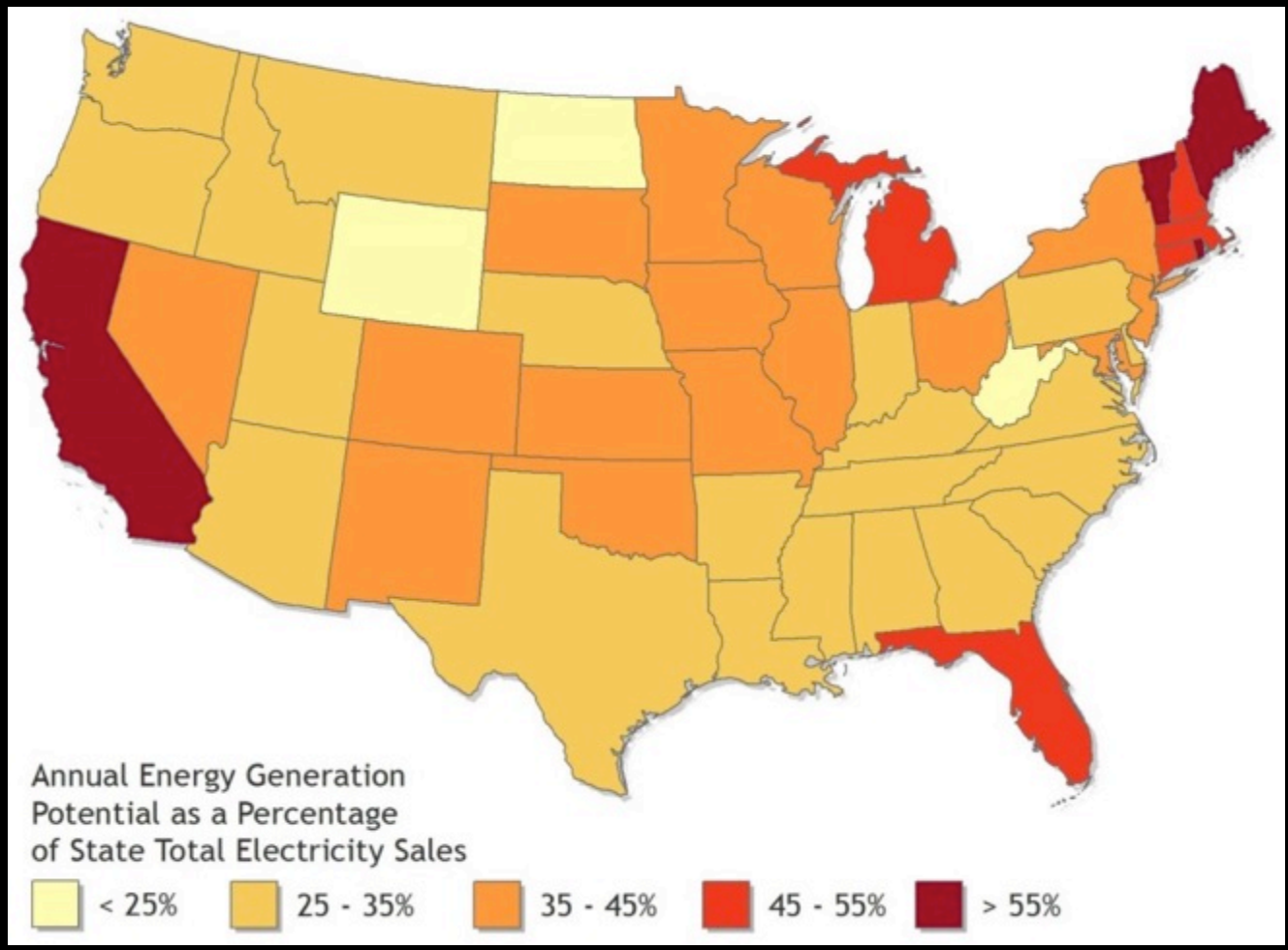
Required area that would be needed in the year 2030 is shown as one large square in the key above and also as distributed around the world relative to use and available sunlight.

- Areas are calculated based on an assumption of 20% operating efficiency of collection devices and a 2000 hour per year natural solar input of 1000 watts per square meter striking the surface.
- These 19 areas distributed on the map show roughly what would be a reasonable responsibility for various parts of the world based on 2009 usage. They would be further divided many times, the more the better to reach a diversified infrastructure that localizes use as much as possible.
- The large square in the Saharan Desert (1/4 of the overall 2030 required area) would power all of Europe and North Africa. Though very large, it is 18 times less than the total area of that desert.
- The definition of “power” covers the fuel required to run all electrical consumption, all machinery, and all forms of transportation. It is based on the US Department of Energy statistics of worldwide Btu consumption and estimates the 2030 usage (678 quadrillion Btu) to be 44% greater than that of 2008.
- Area calculations do not include magenta border lines.

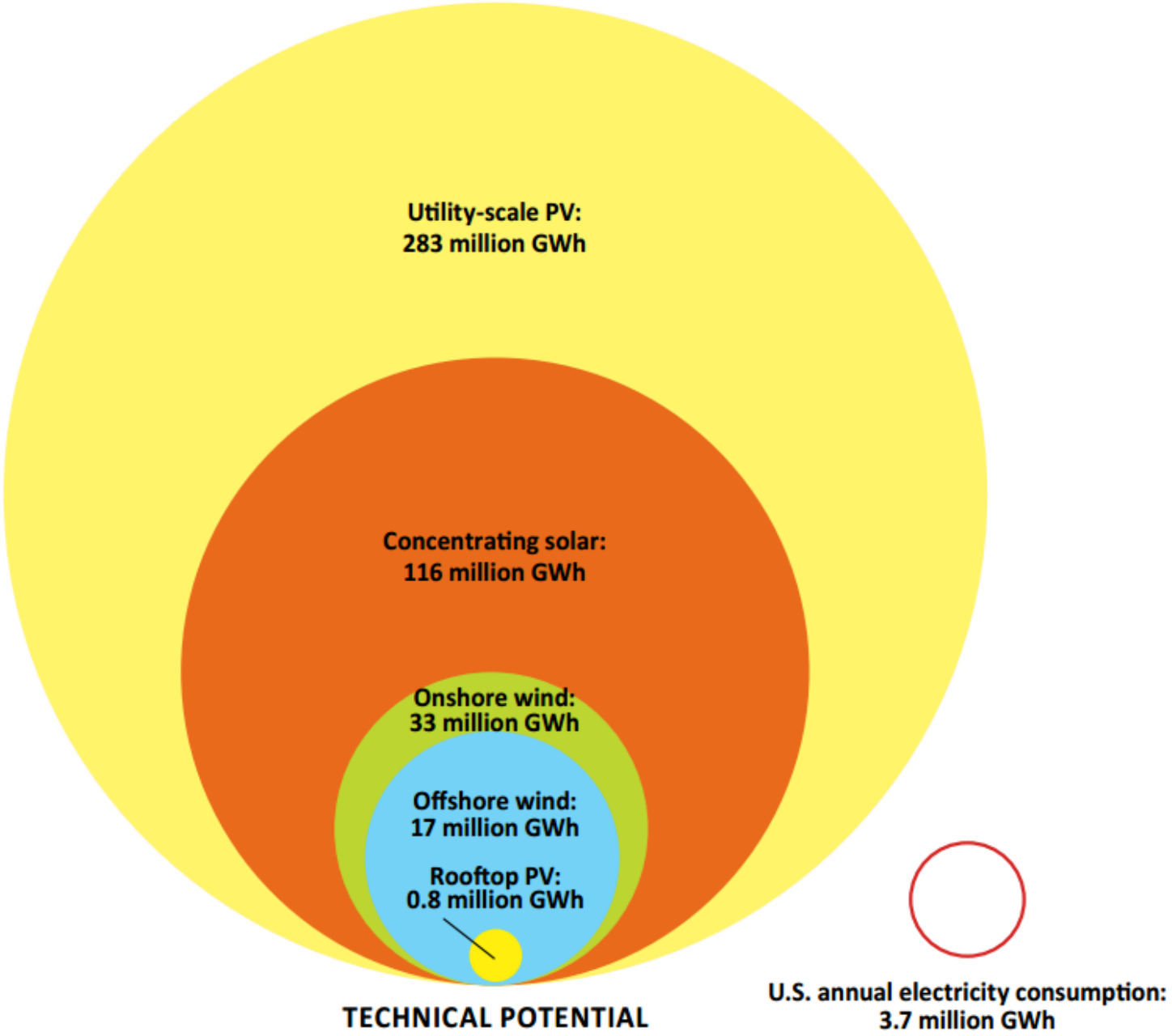
land art generator initiative

Rooftop PV Technical Potential

- California has the greatest potential—rooftop PV could generate 74% of the electricity
- A cluster of New England states could generate more than 45%

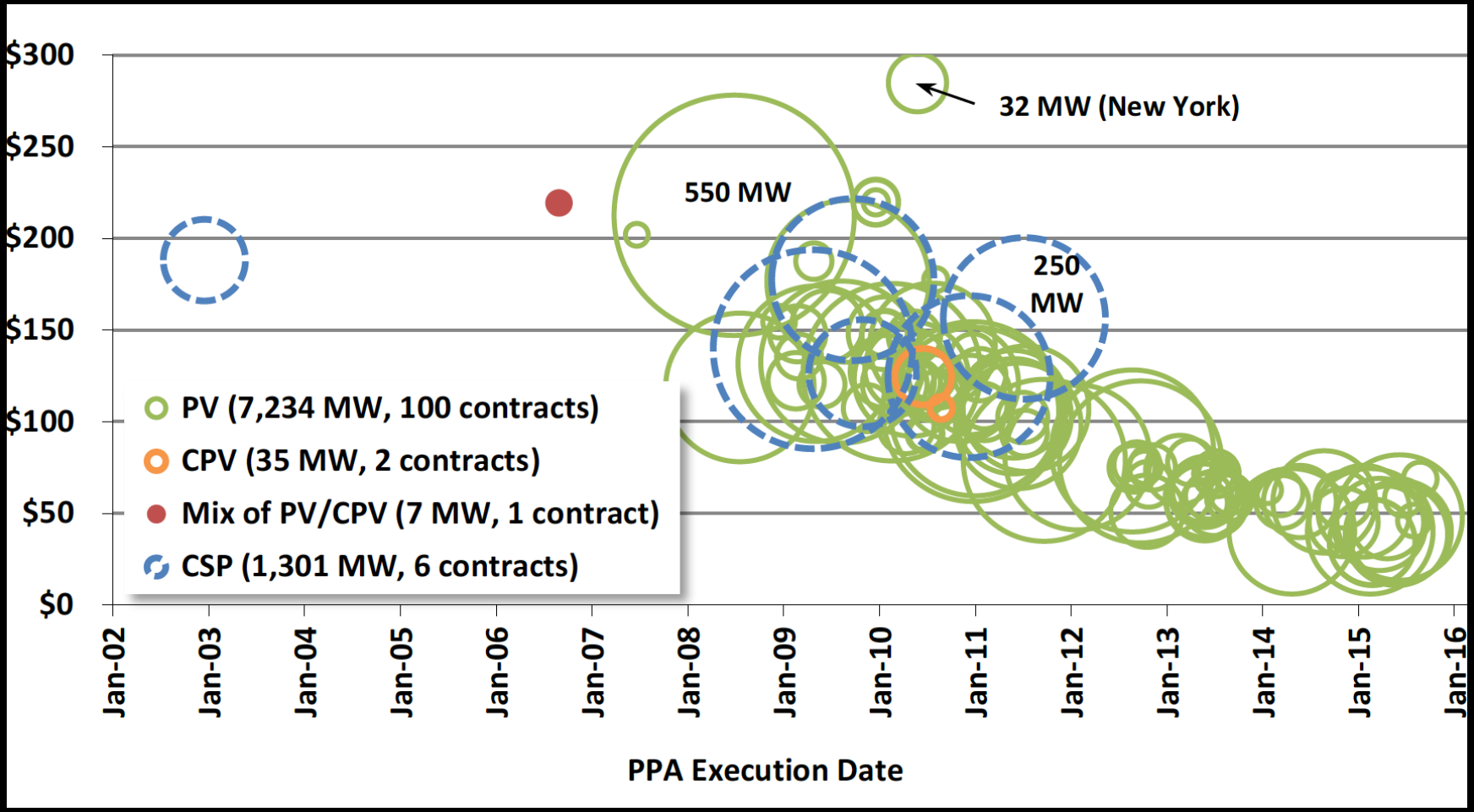


Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment, Gagnon, et al., NREL, January 2016



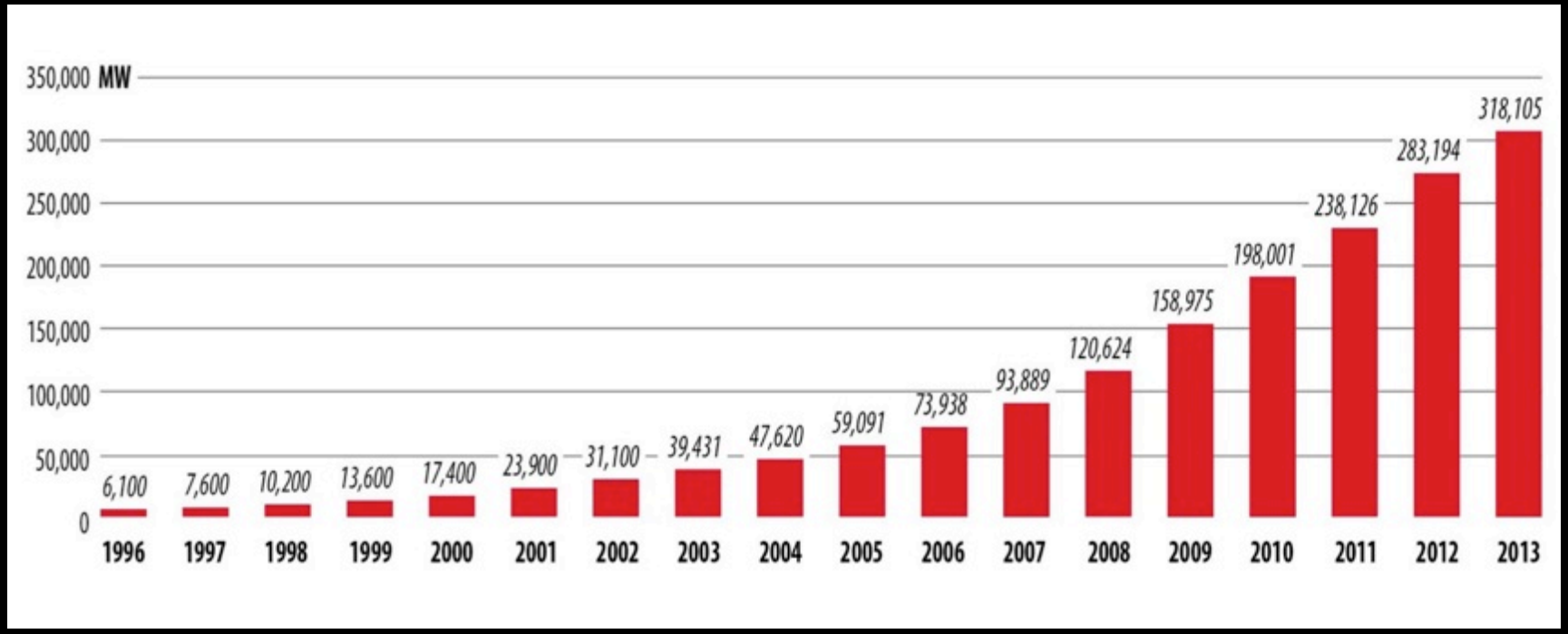
Environment America Research & Policy Center based on NREL data

Costs of Utility Scale Solar in U.S.

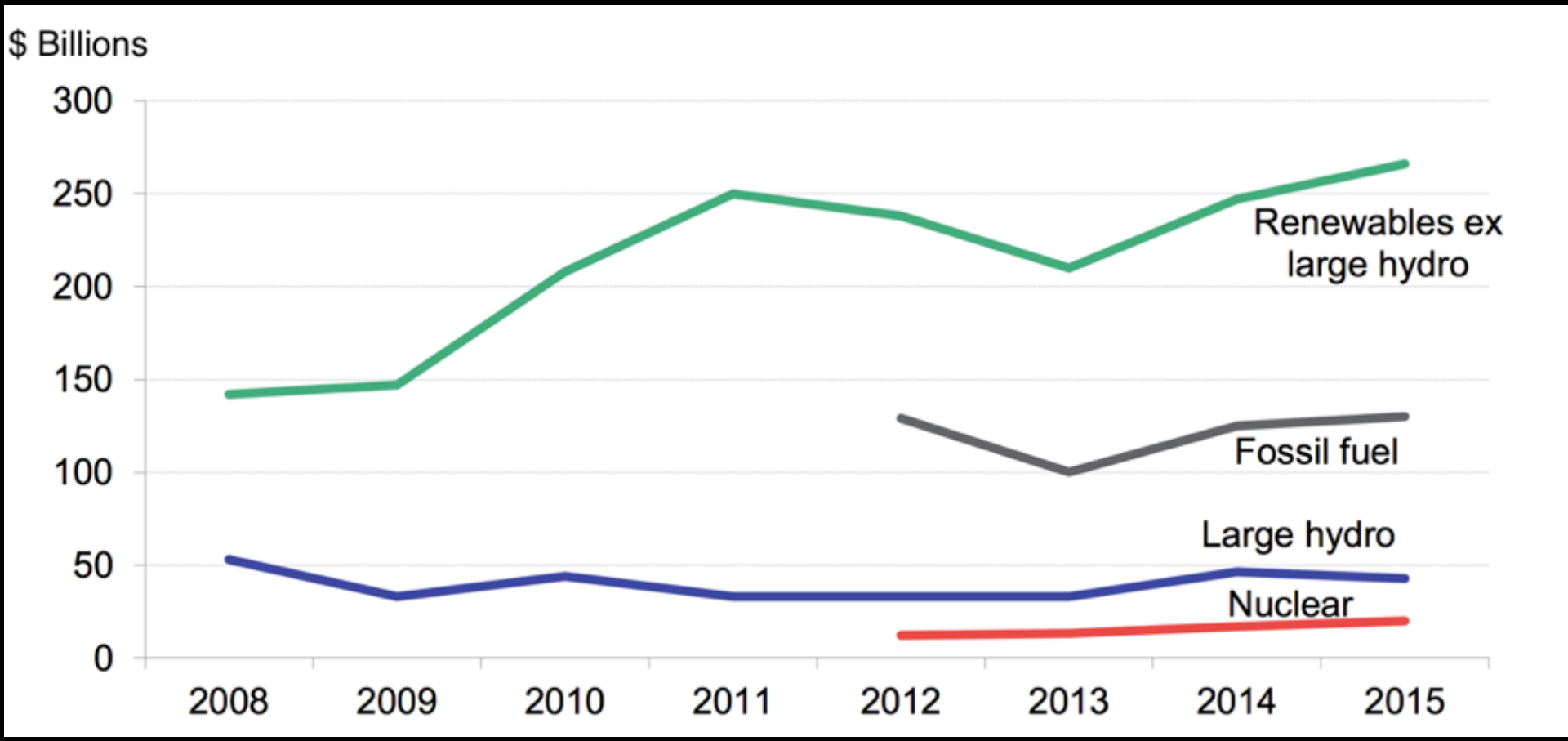


Utility Scale Solar 2014, Bolinger and Seel, Lawrence Berkeley National Laboratory, September 2015

World Wind Power (MW)



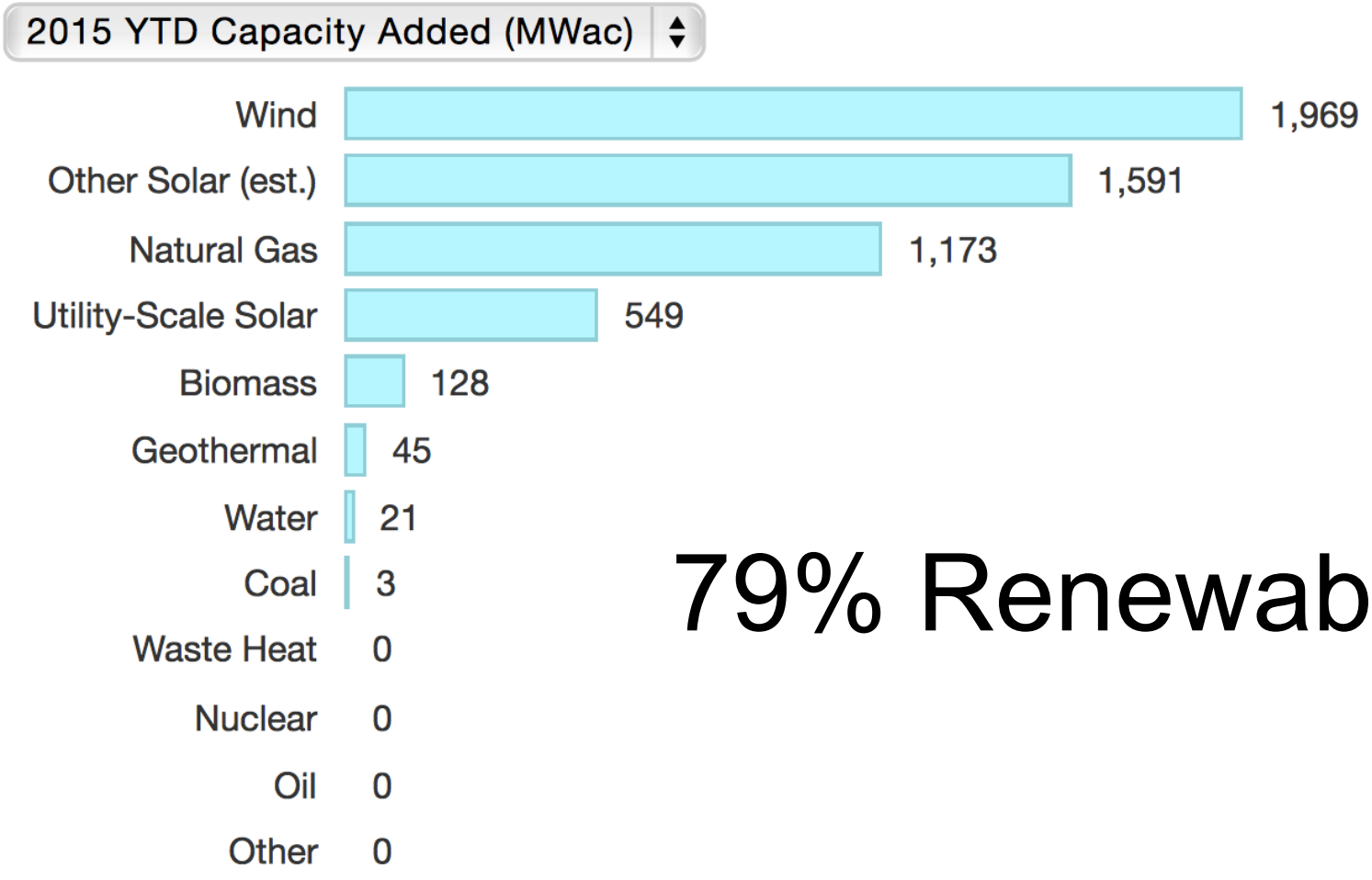
World Investment in Power Capacity



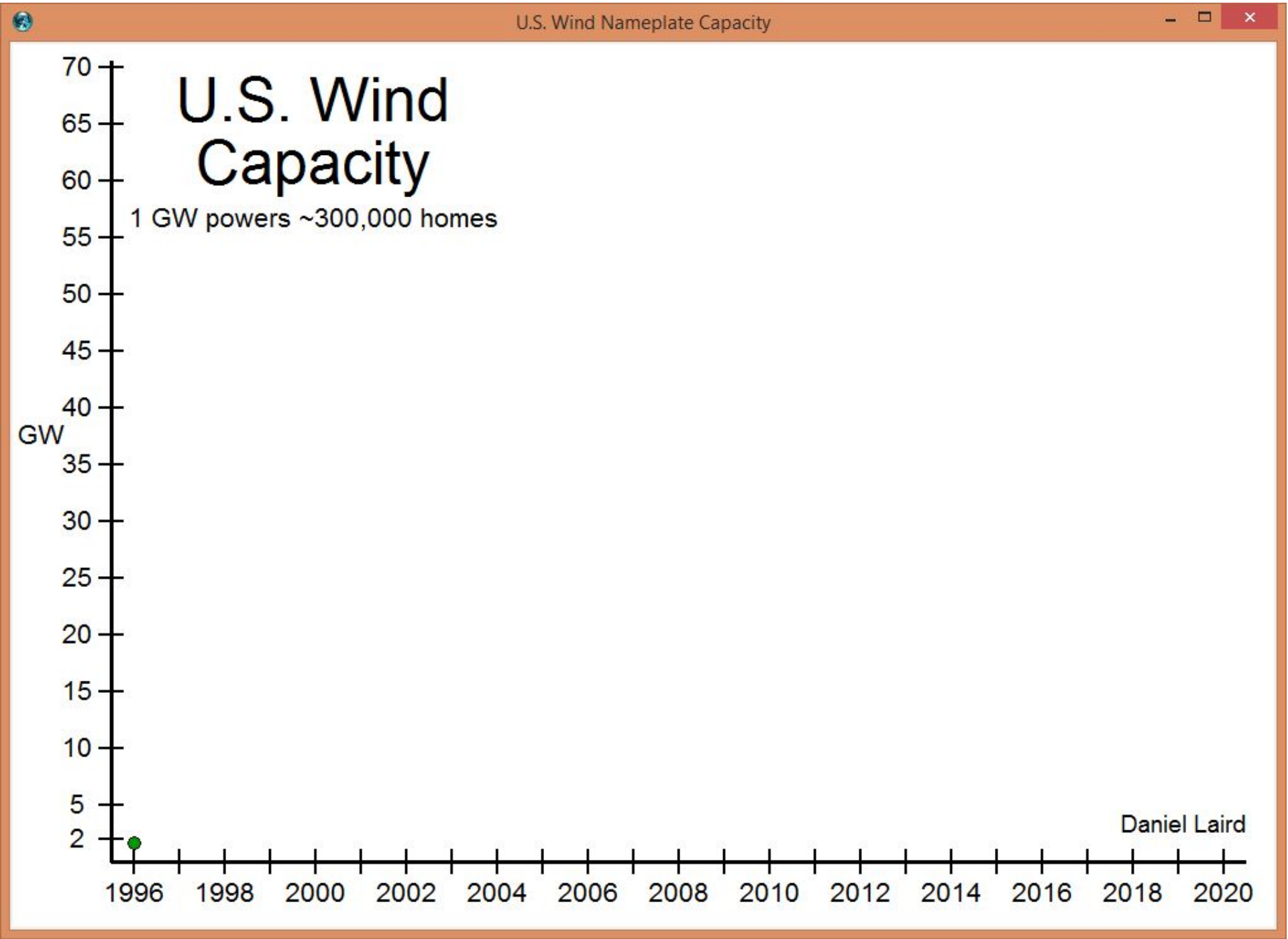
Bloomberg New Energy Finance, UN Environment Programme

New US Electricity Generation Capacity (Jan-June 2015)

"Other Solar" is estimated based on very educated 2015 projections from top solar market researchers and a bit of math and assumptions from CleanTechnica staff.



79% Renewables


U.S. Wind Nameplate Capacity
U.S. Wind Capacity
1 GW powers ~300,000 homes
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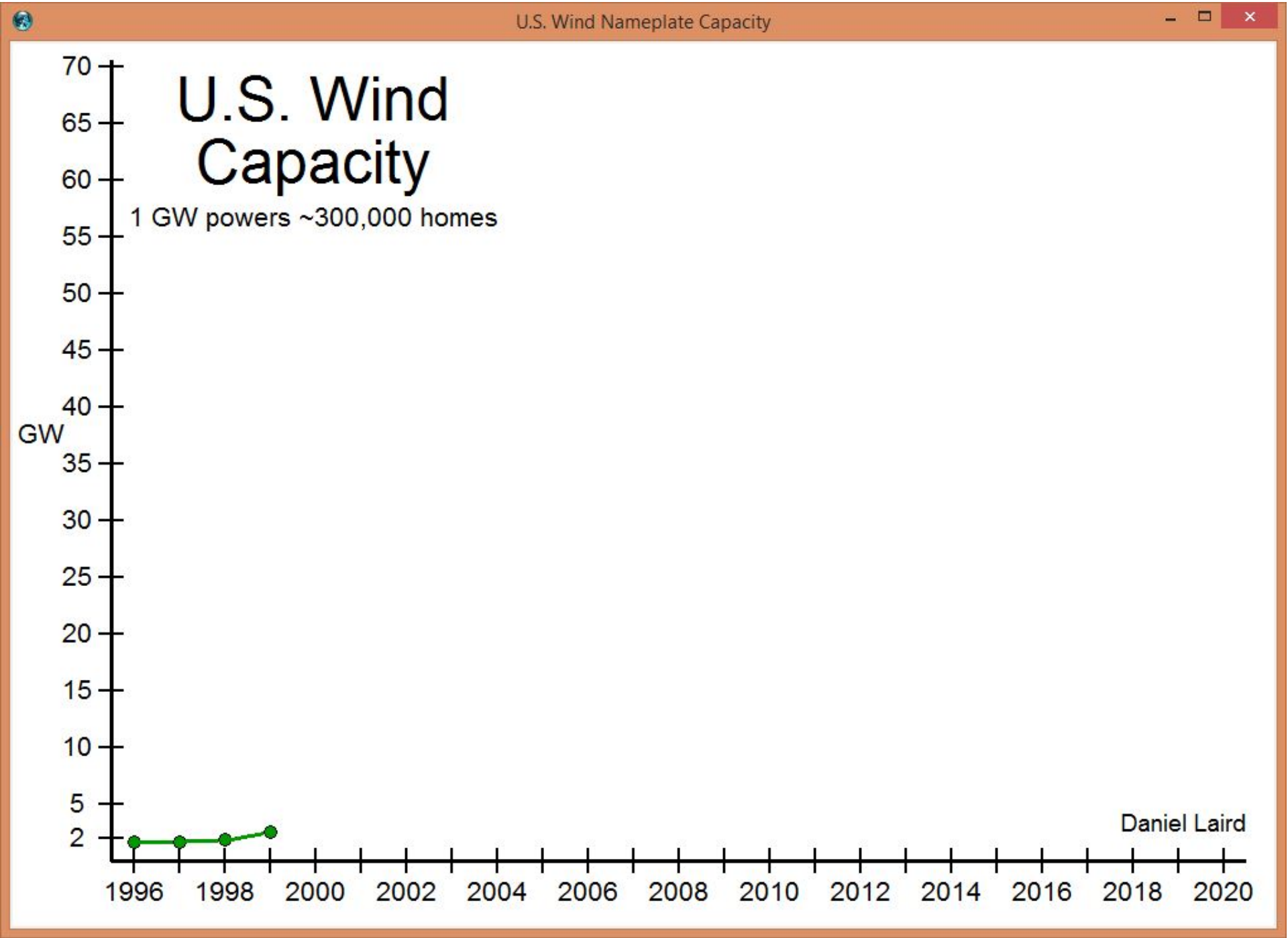
Daniel Laird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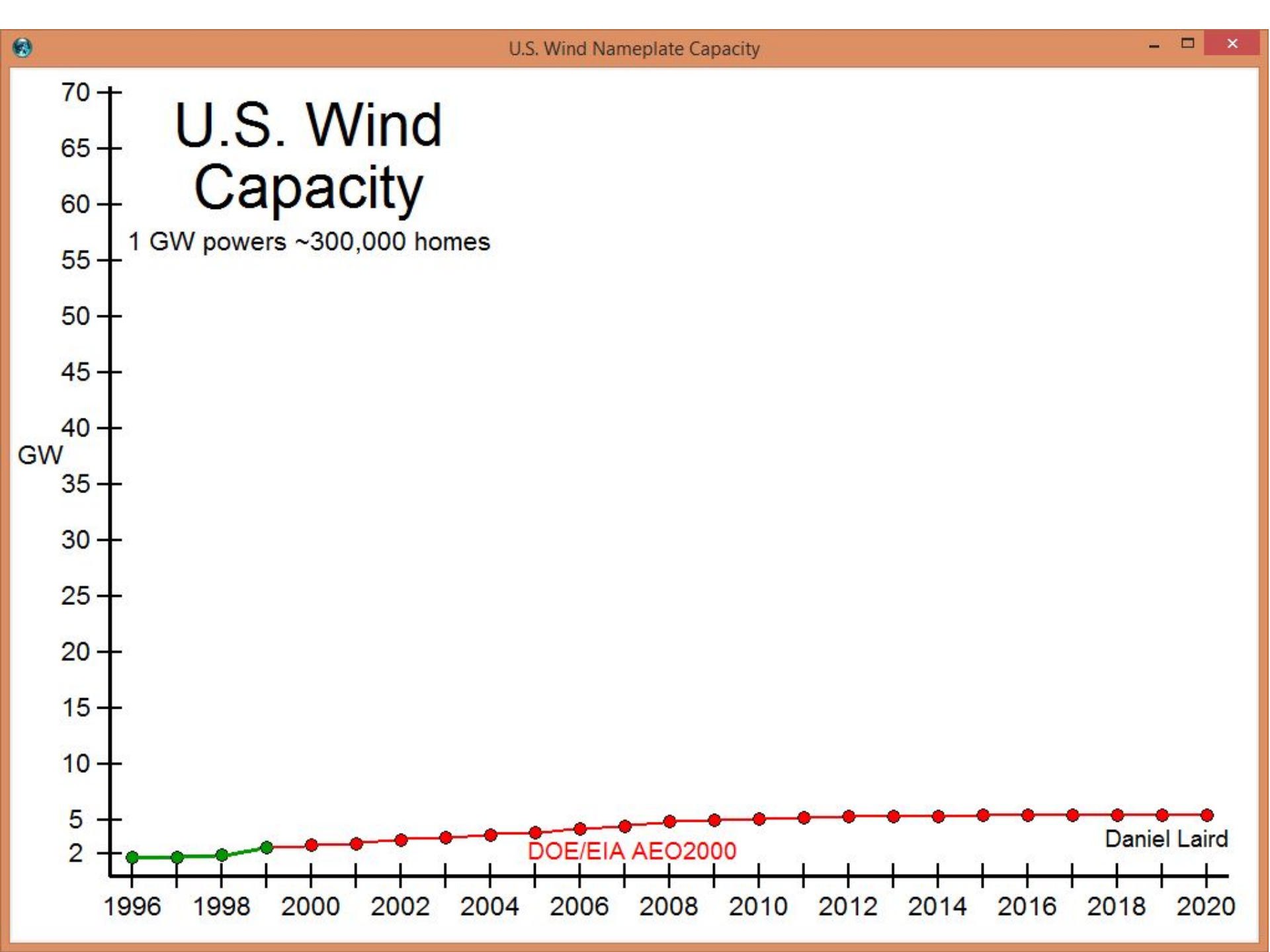
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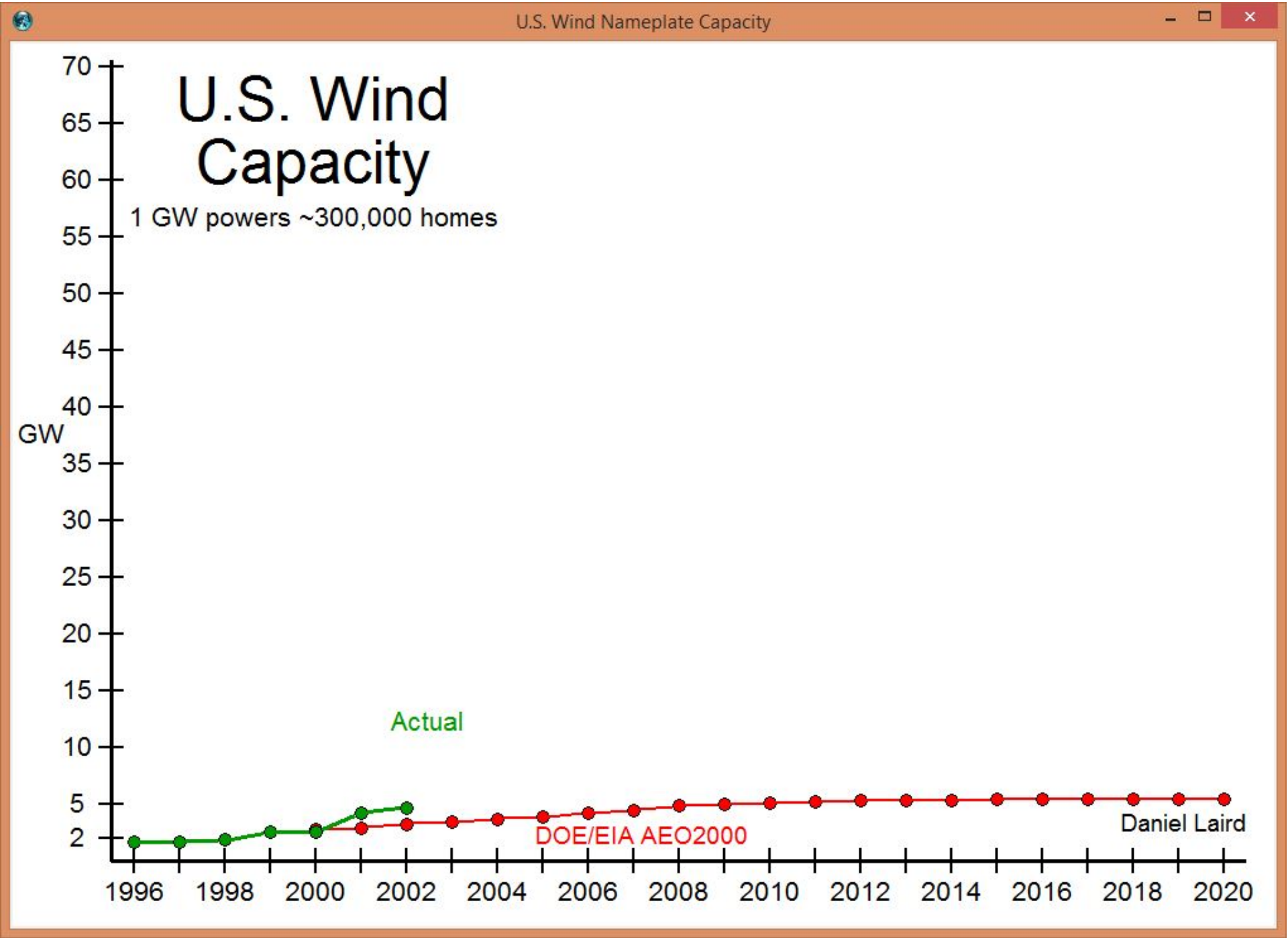
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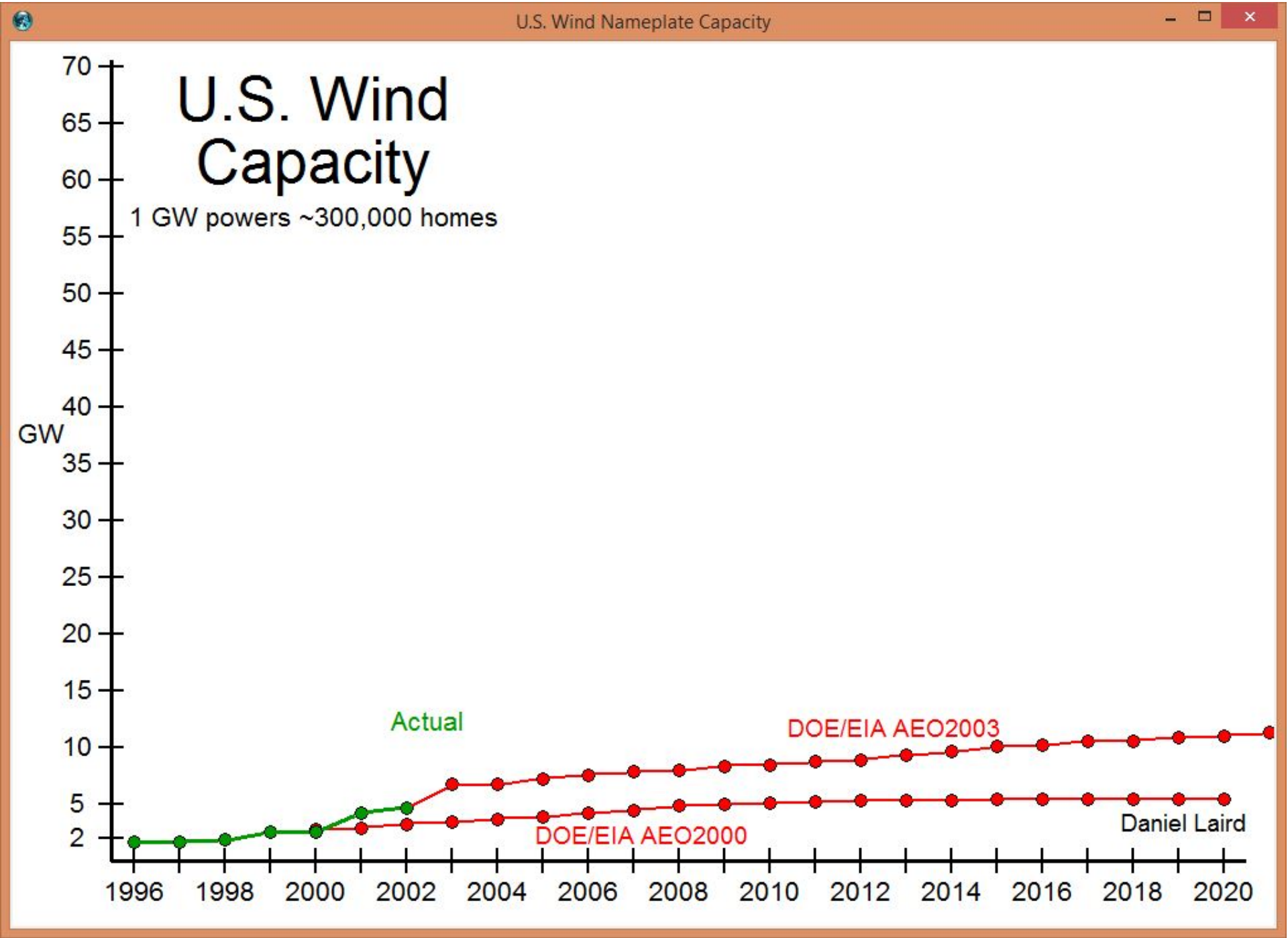
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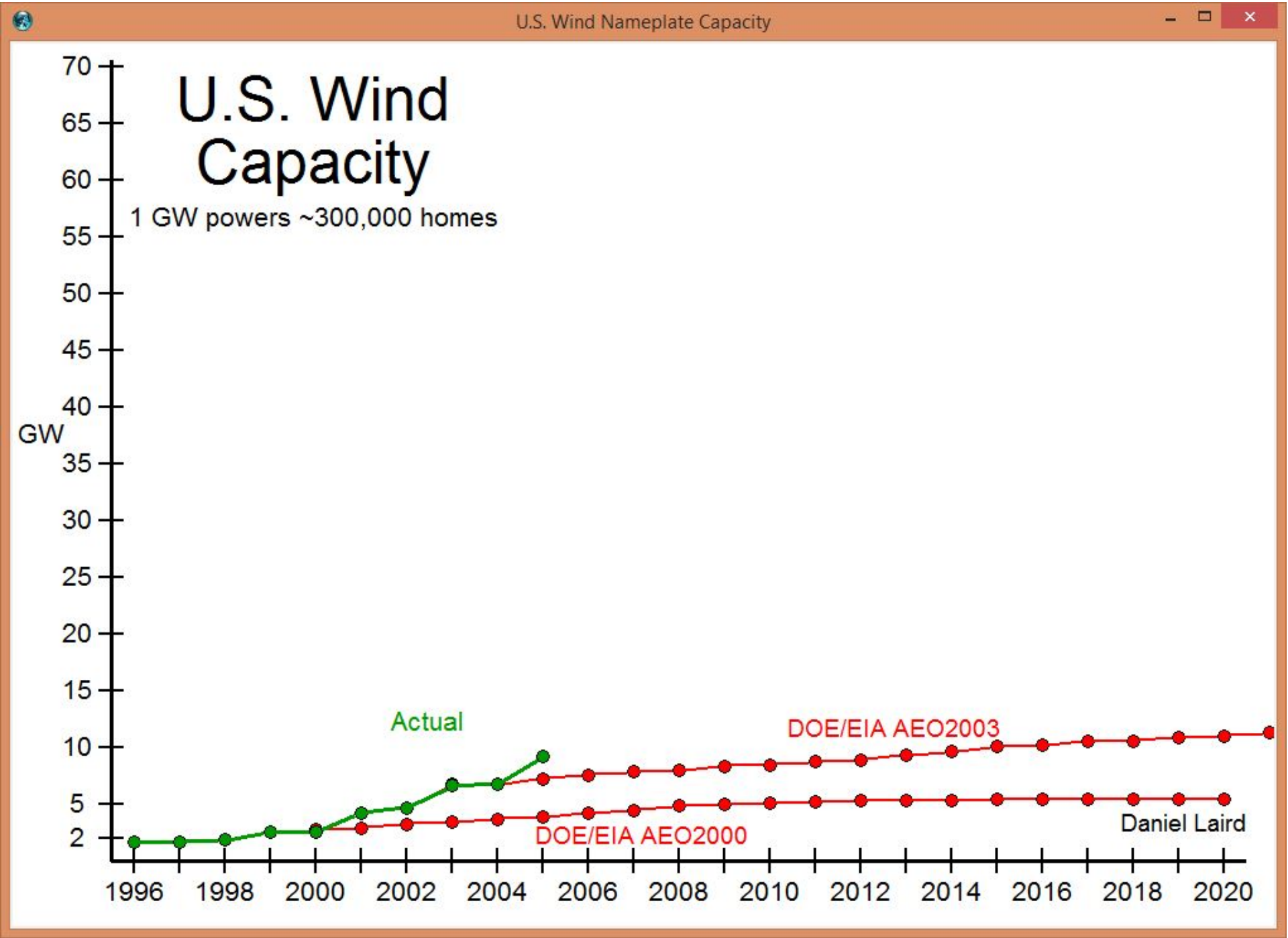
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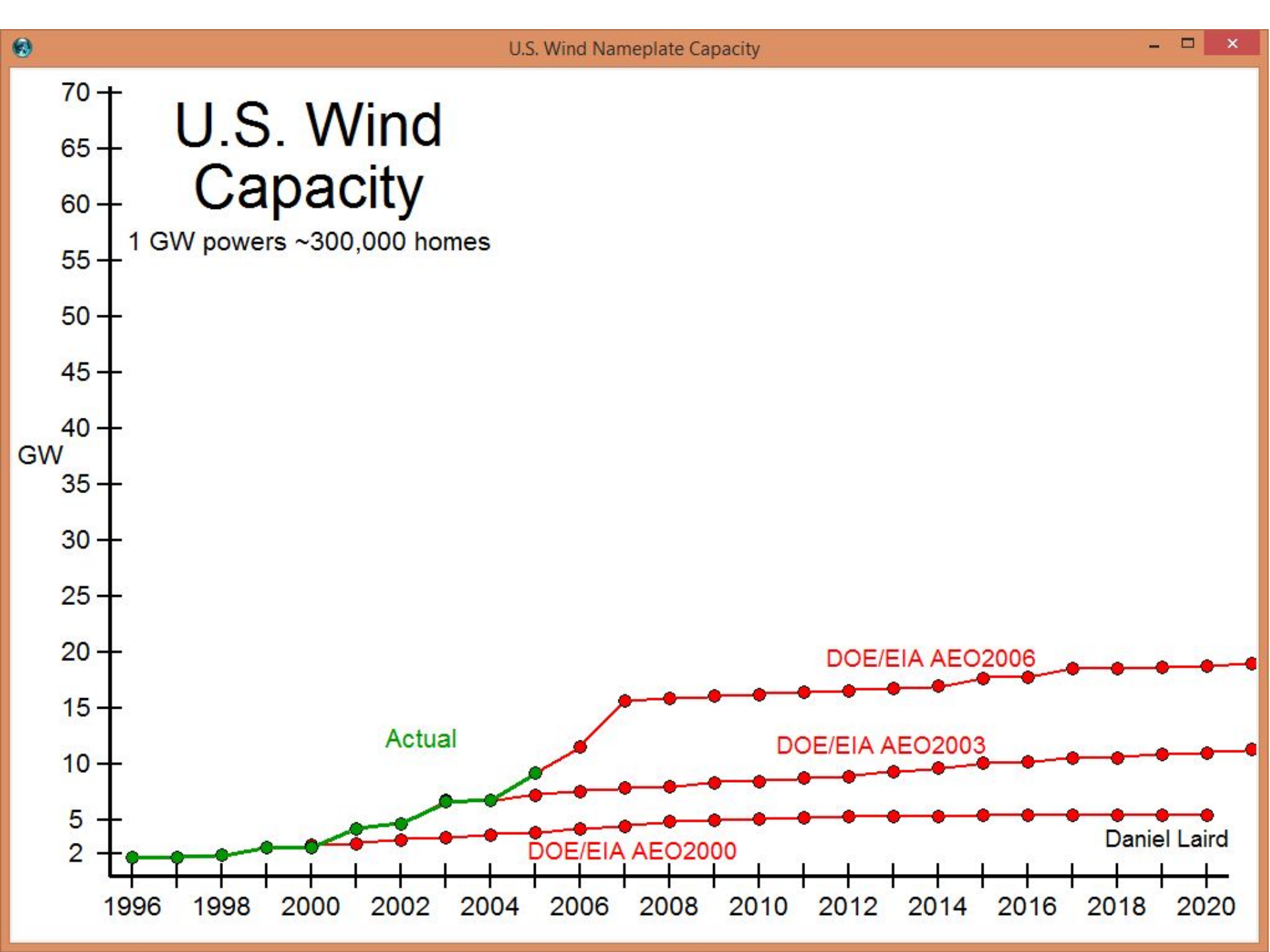
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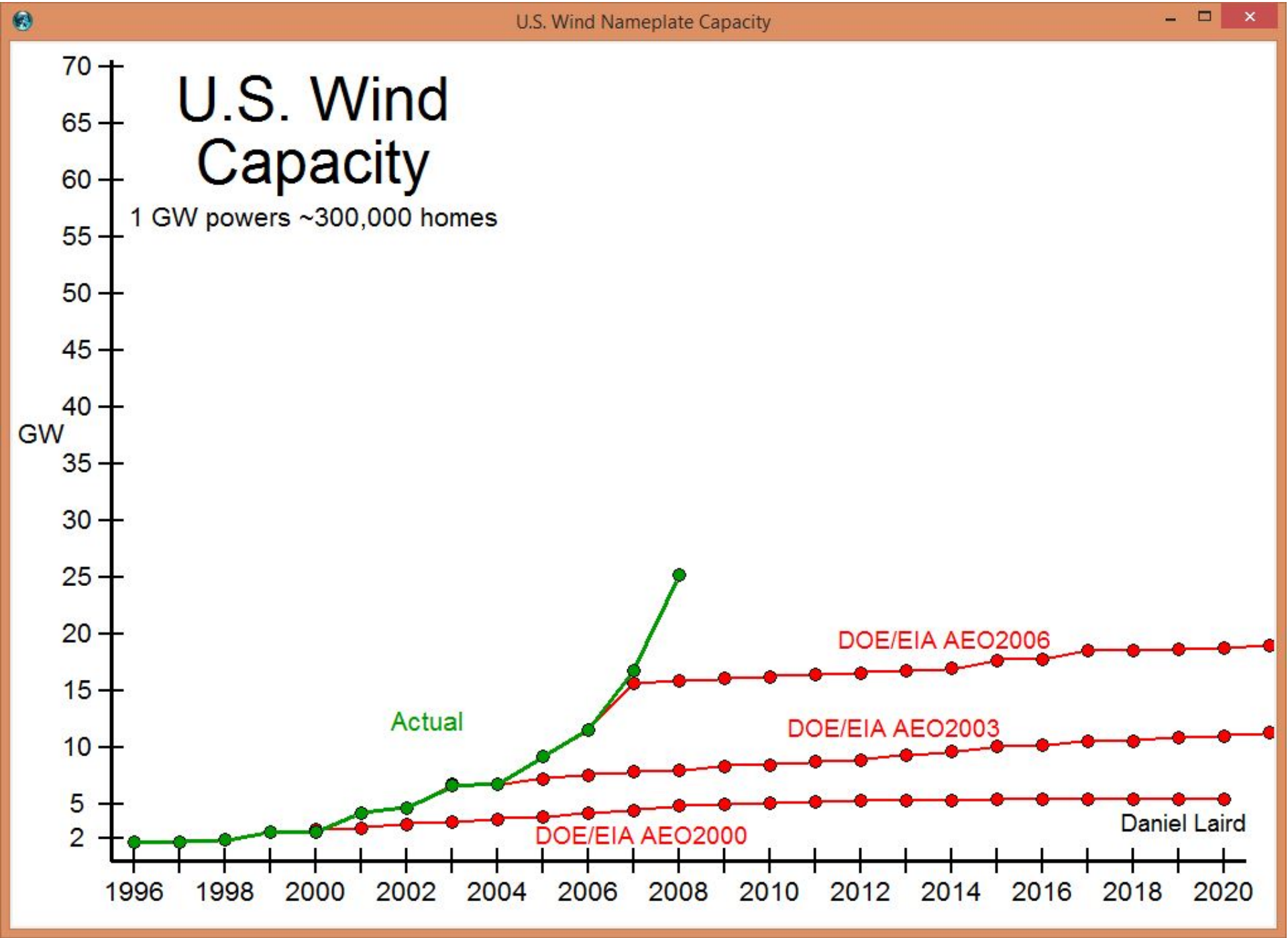
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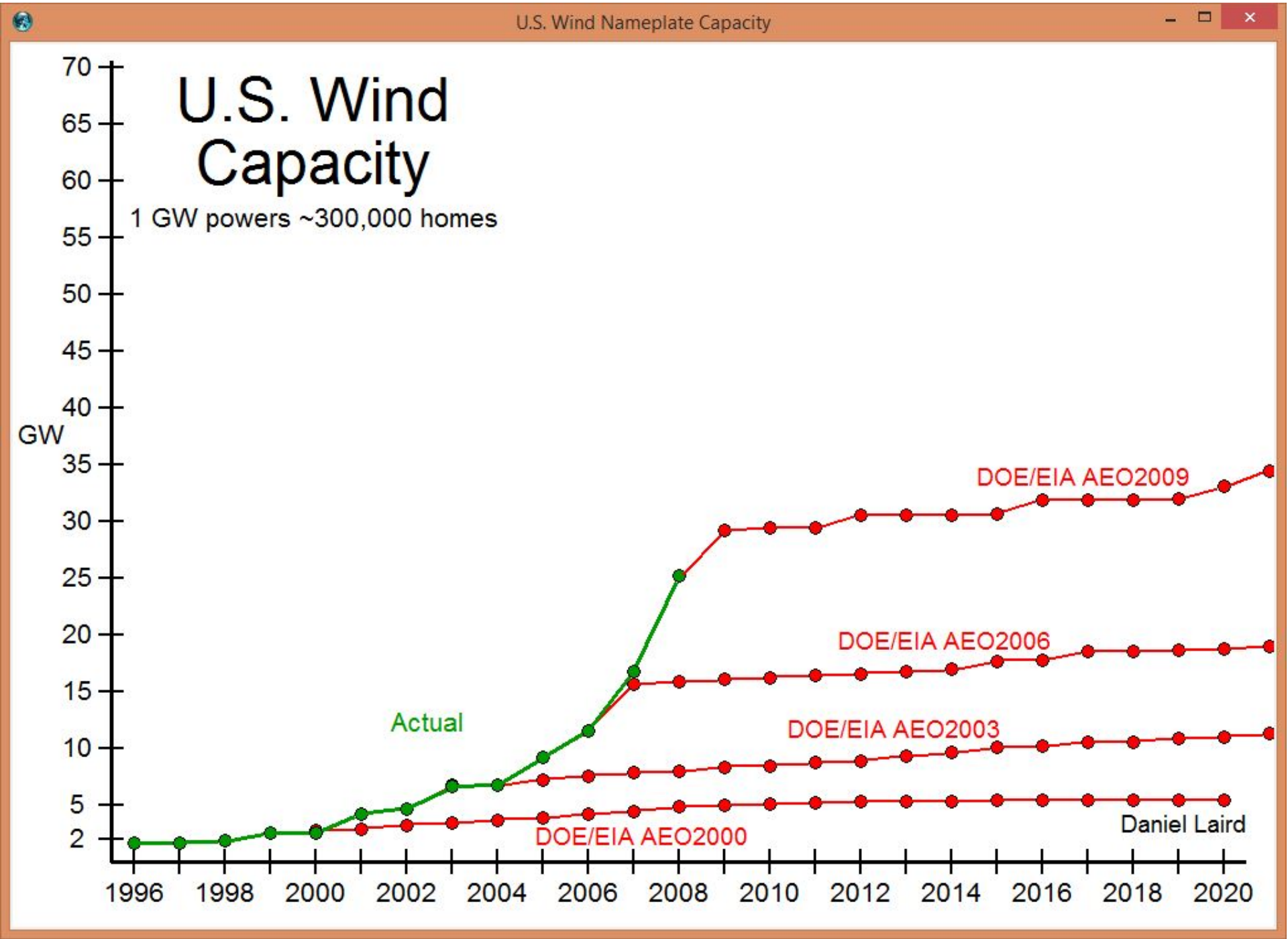
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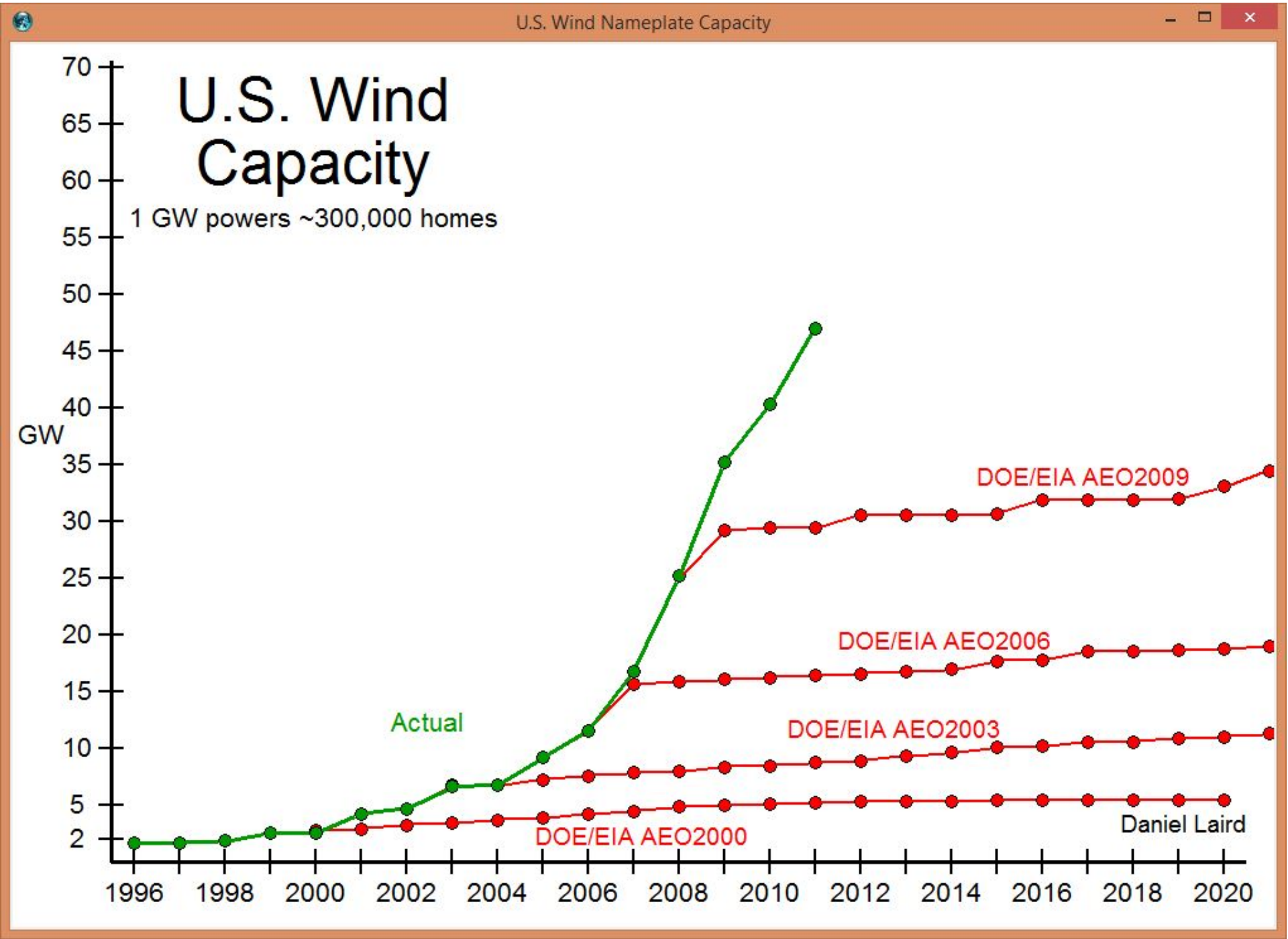
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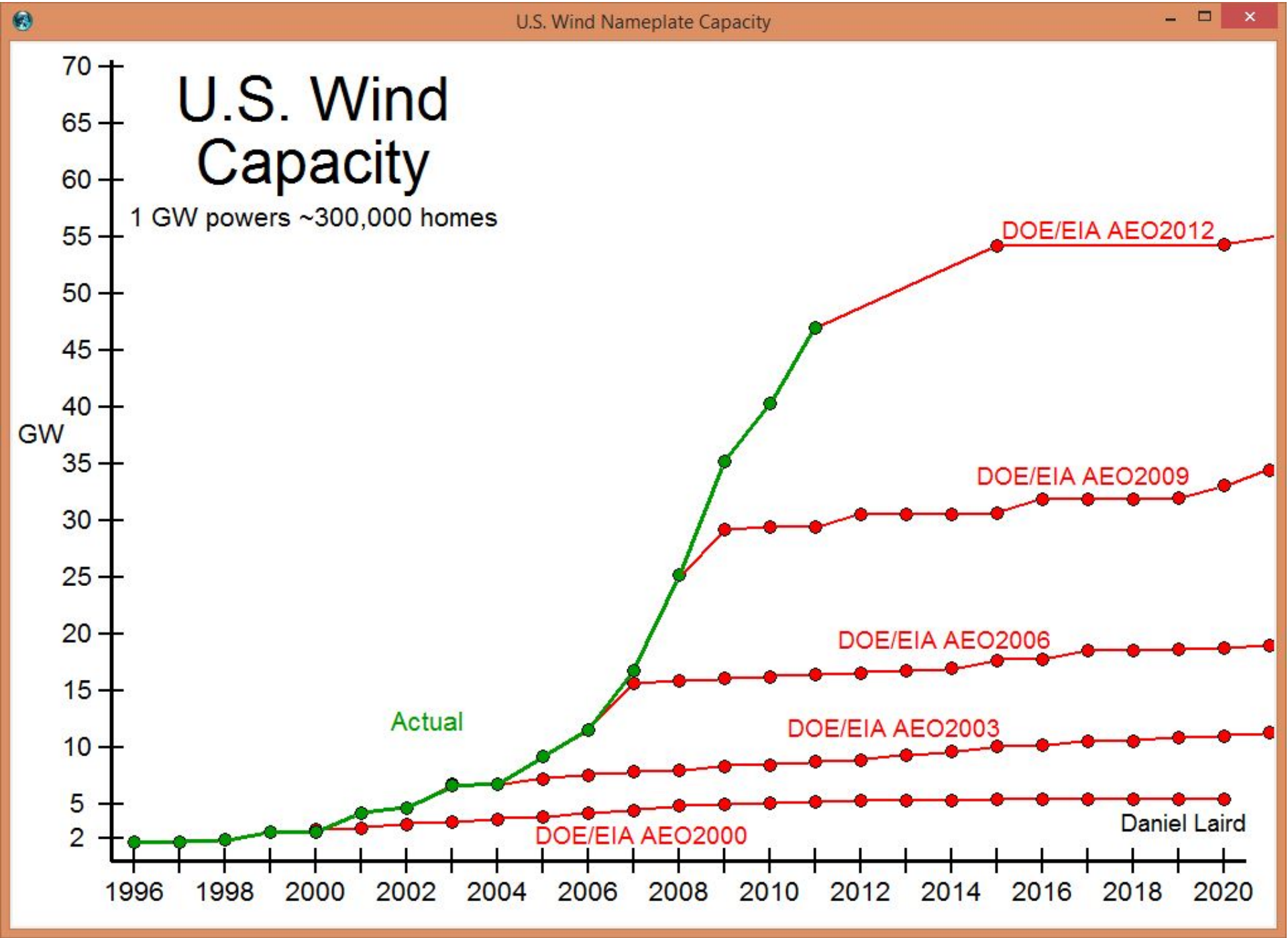
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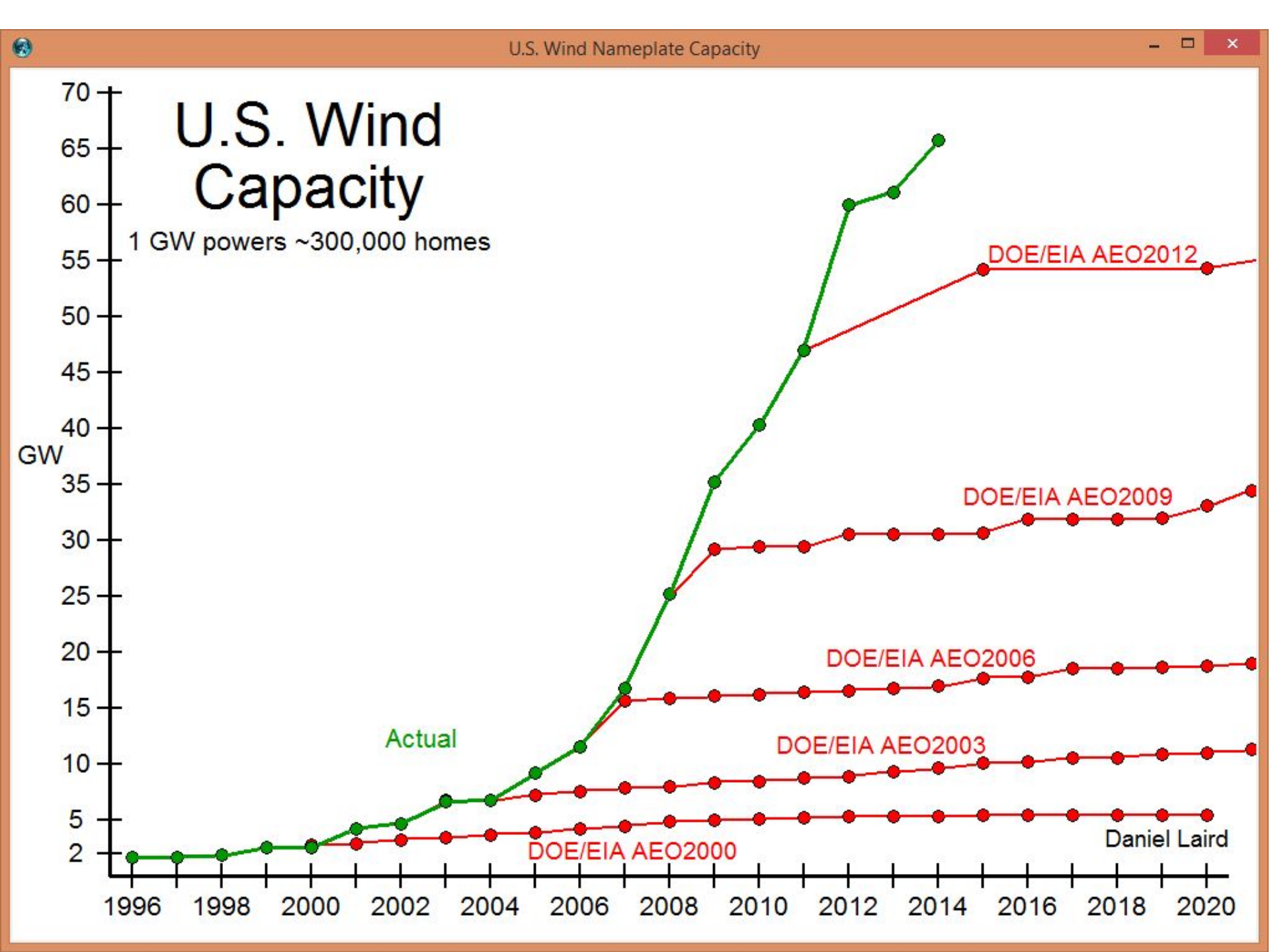
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China and Renewable Energy

NREL
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Chuck Kutscher, Ph.D., P.E.
Director, Buildings and Thermal Systems Center

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Renewable Electricity Futures Study

Volume 1 of 4

Exploration of High-Penetration Renewable Electricity Futures

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80% RE Scenario